

INSTITUTO GEOFISICO DEL PERU
RADIO OBSERVATORIO DE JICAMARCA

REPORT ON
COORDINATED SATELLITE AND
INCOHERENT SCATTER OBSERVATIONS

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ABSTRACT

This document reports measurements taken at the Jicamarca Radar Observatory at Lima, Peru during the Cooperative Sounding Rocket Program. The following types of data were acquired:

- 1) Electron Density and Temperature
- 2) Vertical Plasma Drift
- 3) Electrojet Relative Echo Power Density
- 4) Electrojet Doppler Shift and Condition
- 5) 150 km Echoing Region.

INTRODUCTION

This document reports work carried out at the Jicamarca Radar Observatory of the Instituto Geofísico del Perú (11.95° S, 76.87° W, 2° Dip) during the Cooperative Sounding Rocket Program at Punta Lobos, Chilca, Perú.

As described in the proposal of June 1974, submitted to the National Aeronautics and Space Administration, the general objectives of the coordinated measurements are as follows:

1. Ionospheric studies under quiet and disturbed conditions. The specific objectives are:
 - a) Comparison of electron temperature measurements by rocket-borne probes and the incoherent scatter technique used at the Jicamarca Radar Observatory.
 - b) Observation of the fine structure in the electron density profile to examine the role of vertical transport in layering metallic ions.
 - c) Examination of the role of energetic electrons as a nighttime source of ionization.
2. Measurement of precipitated particle flux. The major objectives are:
 - a) Investigation of the possible influence of soft energetic electron interaction with the thermosphere on the mesosphere via a bremsstrahlung radiation energy transfer process.
 - b) Study of the diurnal behavior of ozone in the equatorial region.
 - c) Determination of the distribution and energy spectrum of the soft energetic particle belt at the magnetic Equator.

- d) Validation of current theories about particle distributions at thermospheric altitudes.
3. Determination of Equatorial Electric and Magnetic Fields:
The specific objectives are:
- a) Three-axis-vector determination of electric fields.
 - b) Total magnetic field measurements.
 - c) Electron density determination.

To this effect we have performed radar measurements of electron concentration and temperature, vertical drift electrojet echo power spectra, doppler shift and condition, and the 150 km echoing region as described under their own headlines and listed in Tables I, II, IV and V.

ELECTRON CONCENTRATION AND TEMPERATURE

We have obtained nine contour plots of electron concentration, N_e , and six contour plots of electron temperature, T_e , as functions of height at the dates and times listed in Table I.

The measuring technique employed has been in use in Jicamarca for a long time now and is thoroughly described by Farley [1969a, b].

The results are presented in 15 figures shown in Appendix A. All electron concentration and temperature measurements were taken at the request of Dr. S. Schutz, Assistant Project Scientist of the University of Illinois, and Dr. R. Goldberg, NASA Project Scientist, in attention to their rocket shots.

VERTICAL DRIFT

We have performed ten continued measurements of vertical plasma drifts as functions of height at the dates and times listed in Table I.

The measuring technique was developed at the Jicamarca Radar Observatory and is fully described by Woodman and Hagfors [1969].

The vertical drift is taken as the average value of drifts between 300 and 400 km, except during the presence of coherent echoes from F-region irregularities that completely mask the incoherently scattered signal and the average is then taken from 400 to 500 km. The dotted segments in the figures indicate the presence of such echoes (equatorial -- spread-F). The 3-hour K_p index for Huancayo is indicated in every graph.

The results are presented in 17 figures shown in Appendix B. After the first set of six graphs a composite picture is presented. There is also another composite graph for the second set of four figures. In addition, five drift profiles are presented in order to give an idea of the actual height variation in our measurements. It is interesting to observe that the last two profiles were obtained so as to encompass the last two rocket flights of the Cooperative -- Rocket Program. The first set of measurements was taken at the request of Dr. R. Goldberg, NASA Project Scientist, while the second one was requested by Dr. N. C. Maynard, NASA Project Scientist, and Dr. J. F. Bedinger, G.C.A. Project Scientist, in attention to their rocket launchings in coordination with AEC satellite passes and Lear jet measurements.

ELECTROJET RELATIVE ECHO POWER DENSITY

We have obtained 35 composite plots of electrojet relative echo power density as functions of frequency deviation at the dates and times listed in Table II.

The measuring technique employed has been amply described by Balsley [1967].

The results are presented in 35 figures shown in Appendix C. All these measurements were taken at the request of Dr. N. C. Maynard, NASA Project Scientist, and Dr. J. F. Be-
dinger, G.C.A. Project Scientist, in attention to their rocket launchings in coordination with AEC satellite passes and Lear jet measurements.

It should be noted that the vertical scale for every graph is not the same due to normalization with respect to a wrong maximum at zero frequency caused by a faulty dc bias in the analog-to-digital converter. Excepting one, always shown in dotted lines, the dc spikes have been omitted in those graphs as can be seen in Fig. 36, for example.

The actual identification of each composite is given in Table III.





ELECTROJET DOPPLER SHIFT AND CONDITION

We have obtained five electrojet doppler shifts and condition plots as functions of time for the periods listed in Table IV.

The measuring technique is the same as the one for the electrojet relative echo power density as given by Balsley [1964] but the presentation is new.

The results are presented in five figures shown in Appendix D. By doppler shift we simply mean the frequency deviation that corresponds to the maximum of the power density

plot and by condition we signify the relative power of type I and type II irregularities. Dr. R. Woodman suggested the ratio a_I/a_{II} as a quantitative measure of electrojet condition. Here a_I is the relative echo power for type I irregularities while a_{II} corresponds to type II irregularities as measured at a frequency half that of a_I . Furthermore, the following convention is adopted:

<u>Range</u>	<u>Condition</u>	<u>Symbol</u>
$0 \leq a_I / a_{II} < 1$	Type II	
$1 \leq a_I / a_{II} < 2$	Marginal	
$2 \leq a_I / a_{II} < 3$	Developed	
$3 \leq a_I / a_{II}$	Saturated	

The heavy line corresponds to the curve a_I/a_{II} while the symbols represent both the electrojet doppler shift and its condition. These measurements were taken at the request of Dr. N. C. Maynard, NASA Project Scientist, and Dr. J. F. Be-
dinger, G.C.A. Project Scientist.

150 KM ECHOING REGION

We have obtained 10 photographs to detect the presence of the 150 km echoing region as described by Balsley [1964] at the times listed in Table V.

These experiments were carried out at the request of Dr. N. C. Maynard, NASA Project Scientist, and are presented in Appendix E.

ACKNOWLEDGEMENT

The author wishes to thank the Jicamarca Radar Observatory Staff for their technical assistance.

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- FARLEY, D. T., Incoherent scatter correlation function measurements, Radio Sci., 4, 935-953, 1969b.
- WOODMAN, R. F. and T. HAGFORS, Methods for the measurement of vertical ionospheric motions near the magnetic equator by incoherent scattering, J. Geophys. Res., 74, 1205-1212, 1969.

TABLE . I

ELECTRON CONCENTRATION AND TEMPERATURE
AND VERTICAL DRIFTS MEASUREMENTS.

PARAMETERS	DATE	INTERVAL (LT)
N_e	May 19-20, 1975	11:40-19:50
N_e	May 20-21, 1975	13:50-23:40
N_e	May 21-22, 1975	14:50-21:40
N_e	May 22-23, 1975	15:10-16:05; 19:30-23:50
N_e	May 23-24, 1975	10:10-10:30; 16:10; 18:50-23:50
N_e	May 24, 1975	08:50-15:10
N_e	May 27, 1975	12:50-15:35
N_e	May 28, 1975	09:50-19:20
N_e	May 29, 1975	14:30-14:55; 21:10-22:50
T_e	May 19, 1975	11:40-19:50
T_e	May 20, 1975	13:50-14:10; 15:50-21:00
T_e	May 21, 1975	16:00-20:10
T_e	May 24, 1975	10:00-15:10
T_e	May 27, 1975	12:30-14:20
T_e	May 28, 1975	09:50-17:40
V_z	May 19-20, 1975	16:00-22:20
V_z	May 20-21, 1975	14:20-23:55
V_z	May 21-22, 1975	15:30-15:40; 17:40-23:50
V_z	May 22-23, 1975	20:10-00:00
V_z	May 23-24, 1975	14:30-01:30; 03:50; 06:10-08:00
V_z	May 24-25, 1975	08:00-15:55
V_z	June 02-03, 1975	12:20-15:30
V_z	June 05-06, 1975	09:30-16:00
V_z	June 06-07, 1975	09:10-13:20
V_z	June 07-08, 1975	09:10-13:10

TABLE II

RELATIVE ECHO POWER DENSITY MEASUREMENTS

DATE	INTERVAL (LT)
JUNE 02, 1975	10:30-11:22
JUNE 02, 1975	13:10-14:32
JUNE 02, 1975	14:50-15:47
JUNE 03, 1975	08:27-08:50
JUNE 03, 1975	09:00-09:10
JUNE 03, 1975	09:12-09:45
JUNE 03, 1975	09:50-10:20
JUNE 03, 1975	10:22-10:50
JUNE 03, 1975	10:52-11:20
JUNE 03, 1975	11:22-11:50
JUNE 03, 1975	12:22-12:50
JUNE 03, 1975	12:52-13:22
JUNE 03, 1975	13:25-13:52
JUNE 03, 1975	13:55-14:27
JUNE 05, 1975	08:47-09:20
JUNE 05, 1975	09:22-09:32
JUNE 05, 1975	09:52-11:27
JUNE 05, 1975	11:42-11:57
JUNE 05, 1975	12:10-12:20
JUNE 05, 1975	12:40-13:07
JUNE 05, 1975	13:10-13:47
JUNE 05, 1975	14:02-14:07
JUNE 06, 1975	08:52-09:45
JUNE 06, 1975	09:47-11:12
JUNE 06, 1975	11:15-11:47

..//

JUNE 06, 1975

12:52-13:57

JUNE 06, 1975

08:45-09:47

JUNE 07, 1975

10:02-10:55

JUNE 07, 1975

10:57,11:50

JUNE 07, 1975

12:12-13:02

JUNE 07, 1975

13:05-13:27

TABLE III

RELATIVE ECHO POWER DENSITY
60° EAST- WEST SPECTRUM

JUNE 02, 1975

COMPOSITE N°1	COMPOSITE N°2	COMPOSITE N°3
10:30	13:10	14:50
10:32	14:02	14:52
10:35	14:07	14:55
10:37	14:12	14:57
10:42	14:17	15:00
10:47	14:20	15:22
10:20	14:22	15:25
10:57	14:25	15:27
11:02	14:30	15:40
11:17	14:32	15:42
11:22		15:45
		15:47

JUNE 03, 1975

COMPOSITE N°1	COMPOSITE N°2	COMPOSITE N°3
08:27	09:00	09:12
08:30	09:05	09:15
08:32	09:07	09:17
08:37	09:10	09:20
08:40		09:22
08:42		09:25
08:45		09:30
08:47		09:37
08:50		09:40
		09:42
		09:45

..//

JUNE 03, 1975

COMPOSITE N°4

09:50
09:52
09:55
~~09:57~~
10:02
10:05
10:07
10:10
10:12
10:15
10:17
10:20

COMPOSITE N°5

10:22
10:25
10:27
~~10:30~~
10:32
10:35
10:37
10:40
10:42
10:45
10:47
10:50

COMPOSITE N°6

10:52
10:55
10:57
11:00
~~11:02~~
11:05
11:07
11:10
11:12
11:15
11:17
11:20

COMPOSITE N°7

11:22
11:25
11:27
11:30
11:32
11:35
11:37
11:40
11:42
11:45
11:47
~~11:50~~

COMPOSITE N°8

11:52
11:55
11:57
12:00
12:02
12:05
12:07
12:10
12:12
12:15
12:17
~~12:20~~

COMPOSITE N°9

12:22
12:25
12:27
12:30
12:32
12:35
12:37
12:40
12:42
12:45
12:47
12:50

//..

..//

JUNE 03, 1975

COMPOSITE N°10

12:52

12:55

12:57

13:00

13:02

13:07

13:10

13:12

13:15

13:17

13:20

13:22

COMPOSITE N°11

13:25

13:27

13:30

13:32

13:35

13:37

13:40

13:42

13:45

13:47

13:50

13:52

COMPOSITE N°12

13:55

13:57

14:00

14:02

14:05

14:07

14:10

14:12

14:15

14:17

14:20

14:22

14:25

14:27

JUNE 05, 1975

COMPOSITE N°10

08:47

08:50

08:52

08:55

09:00

09:02

09:07

09:10

09:12

09:17

09:20

COMPOSITE N°2

09:22

09:25

09:27

09:30

09:32

COMPOSITE N°3

09:52

~~09:55~~

10:10

10:12

10:25

10:27

11:02

11:05

11:07

11:22

11:25

11:27

//..

..//

JUNE 05, 1975

COMPOSITE N°4

11:42
11:45
11:47
11:50
11:52
11:55
11:57

COMPOSITE N°5

12:10
12:12
12:15
12:17
12:20

COMPOSITE N°6

12:40
12:42
12:45
12:47
13:02
13:05
13:07

COMPOSITE N°7

~~13:10~~
13:12
13:35
13:37
13:40
13:42
13:45
13:47

COMPOSITE N°8

~~14:02~~
14:05
14:07

JUNE 06, 1975

COMPOSITE N°1

08:52
08:55
08:57
09:00
09:02
09:05
09:07
09:22
09:25
09:27
09:42
09:45

COMPOSITE N°2

09:47
10:07
10:10
10:45
10:50
10:52
10:57
11:00
11:05
11:07
11:10
11:12

COMPOSITE N°3

11:15
11:17
11:22
11:25
11:27
11:30
11:32
11:35
11:37
11:40
11:42
11:47

..//

JUNE 06, 1975

COMPOSITE N°4	COMPOSITE N°5
11:52	12:52
11:55	12:57
11:57	13:02
12:00	13:40
12:02	13:42
12:05	13:45
12:07	13:47
12:22	13:52
12:25	13:55
12:27	13:57
12:47	

JUNE 07, 1975

COMPOSITE N°1	COMPOSITE N°2	COMPOSITE N°3
08:45	10:02	10:57
08:47	10:05	11:20
09:02	10:07	
09:05	10:10	COMPOSITE N°4
09:07	10:15	
09:20	10:17	11:22
09:22	10:30	11:25
09:25	10:32	
09:27	10:35	COMPOSITE N°5
09:42	10:37	11:27
09:45	10:50	11:50
09:47	10:52	
	10:55	

///.

..//

JUNE 07, 1975 .

COMPOSITE N°6	COMPOSITE N°7
12:12	13:05
12:15	13:07
12:17	13:10
12:20	13:20
12:22	13:22
12:35	13:25
12:37	13:27
12:40	
12:42	
12:45	
12:47	
13:02	

TABLE IV

ELECTROJET DOPPLER SHIFT AND CONDITION

DATE	INTERVAL (LT)
JUNE 02, 1975	10:37-11:17; 12:07; 13:10; 14:02-14:32; 14:50-15:00; 15:22-15:27; 15:40-15:47
JUNE 03, 1975	08:27-14:27
JUNE 05, 1975	08:47-09:32; 09:52-10:27; 11:02-11:07; 11:22-11:27; 11:42-12:20; 12:40-13:12; 13:35-13:47; 14:02-14:07
JUNE 06, 1975	08:52-09:07; 09:22-09:27; 09:42-09:47; 10:00; 10:07; 10:45-12:07; 10:22-10:27; 10:47; 13-02; 13:40-13:57
JUNE 07, 1975	10:45-10:47; 09:02-09:07; 09:20-09:27; 09:42-09:47; 10:02-10:17; 10:30-10:57; 11:20-11:27; 11:50; 12:12-13:27

TABLE V

150 KM ECHOING REGION

JUNE 07, 1975

LOCAL TIME

10:00

11:04

11:12

11:13

11:36

11:56

12:00

12:03

11:06

12:27

· APPENDIX A ·

ELECTRON CONCENTRATION AND TEMPERATURE

FIGURE CAPTIONS

Fig. 1 to 9 Electron Density contour as function of height
at local times indicated in the figure.

Fig. 10 to 15 Same as above but the electron temperature con
tour is shown.

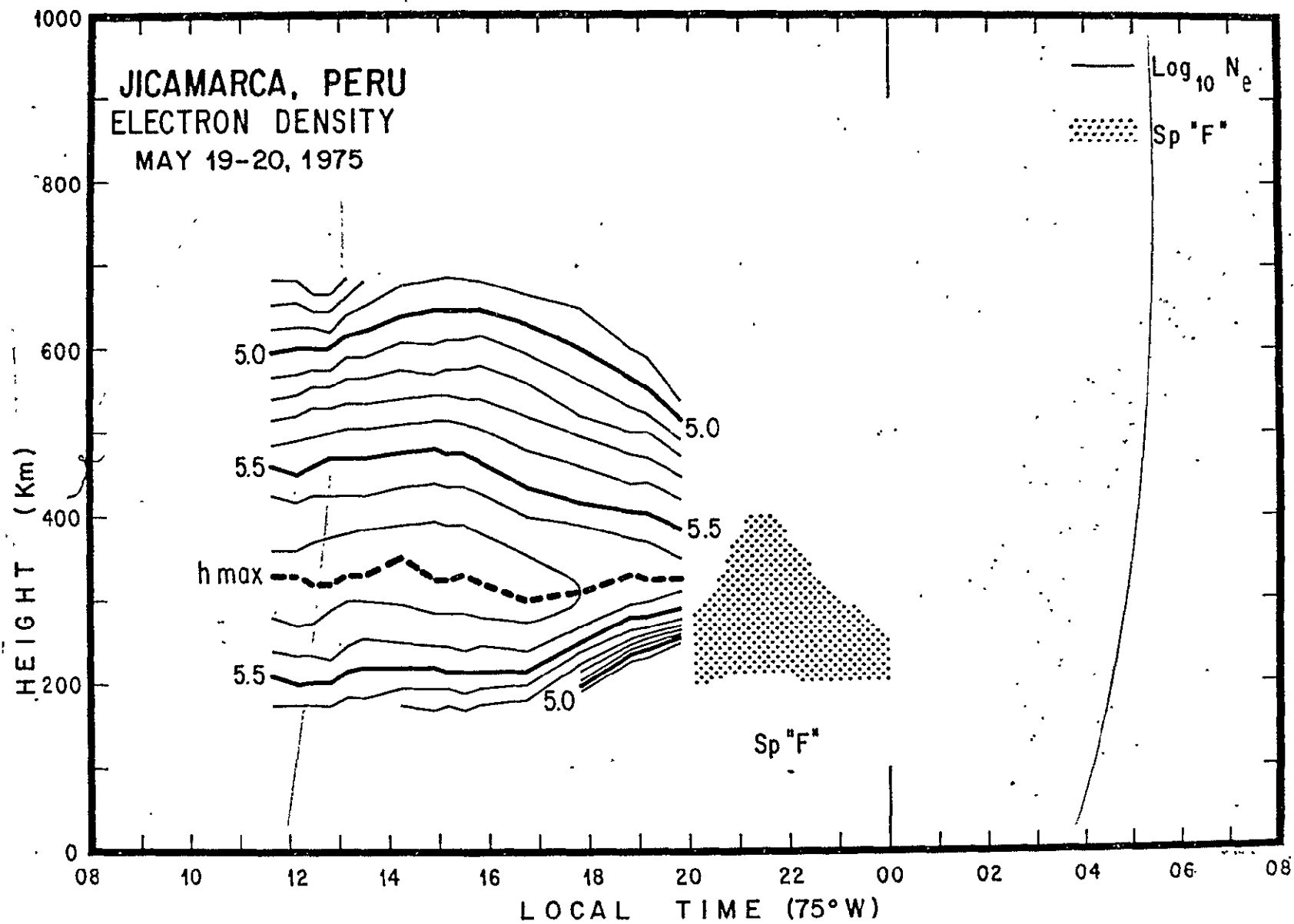


Fig. 1

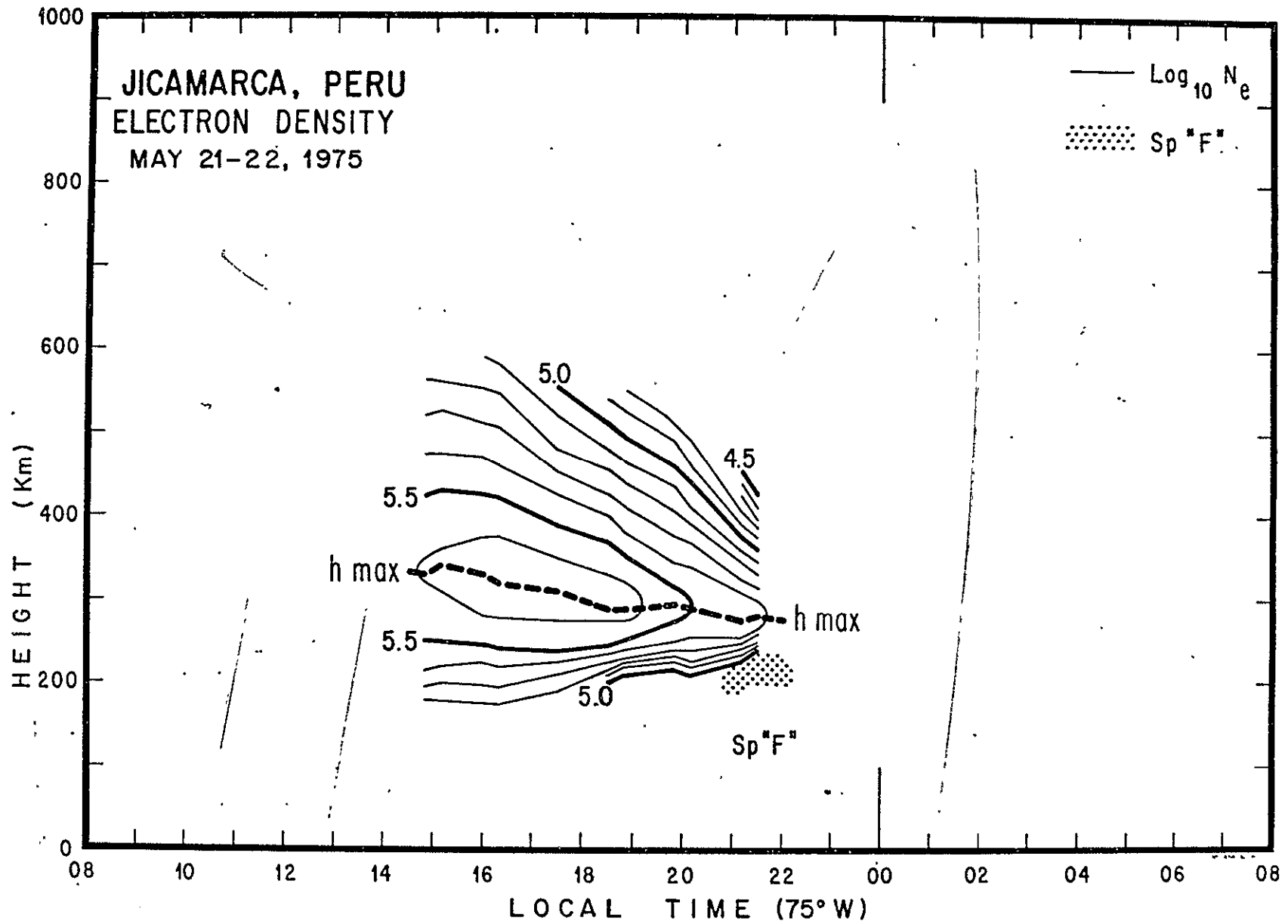


Fig. 3

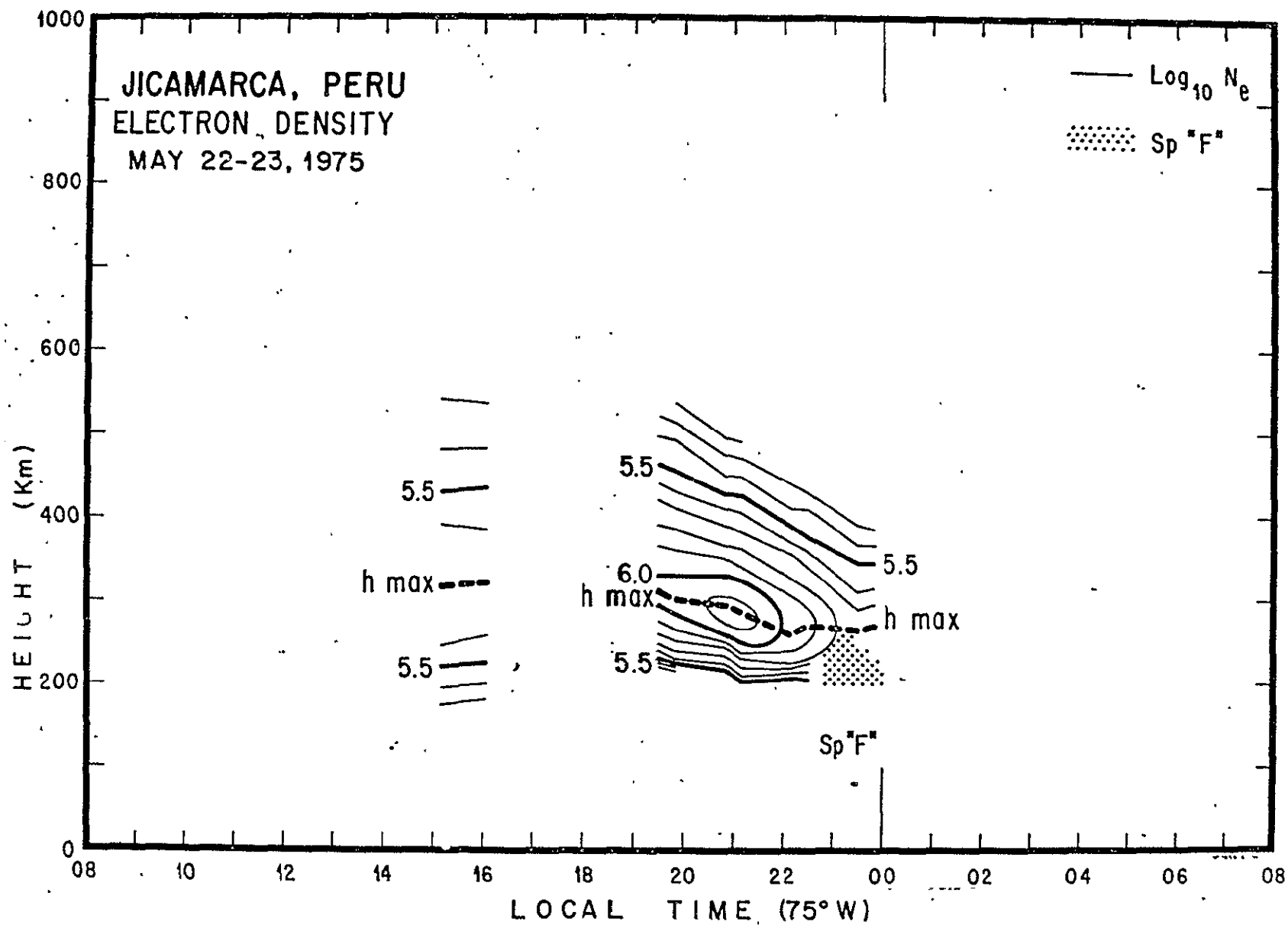


Fig. 4

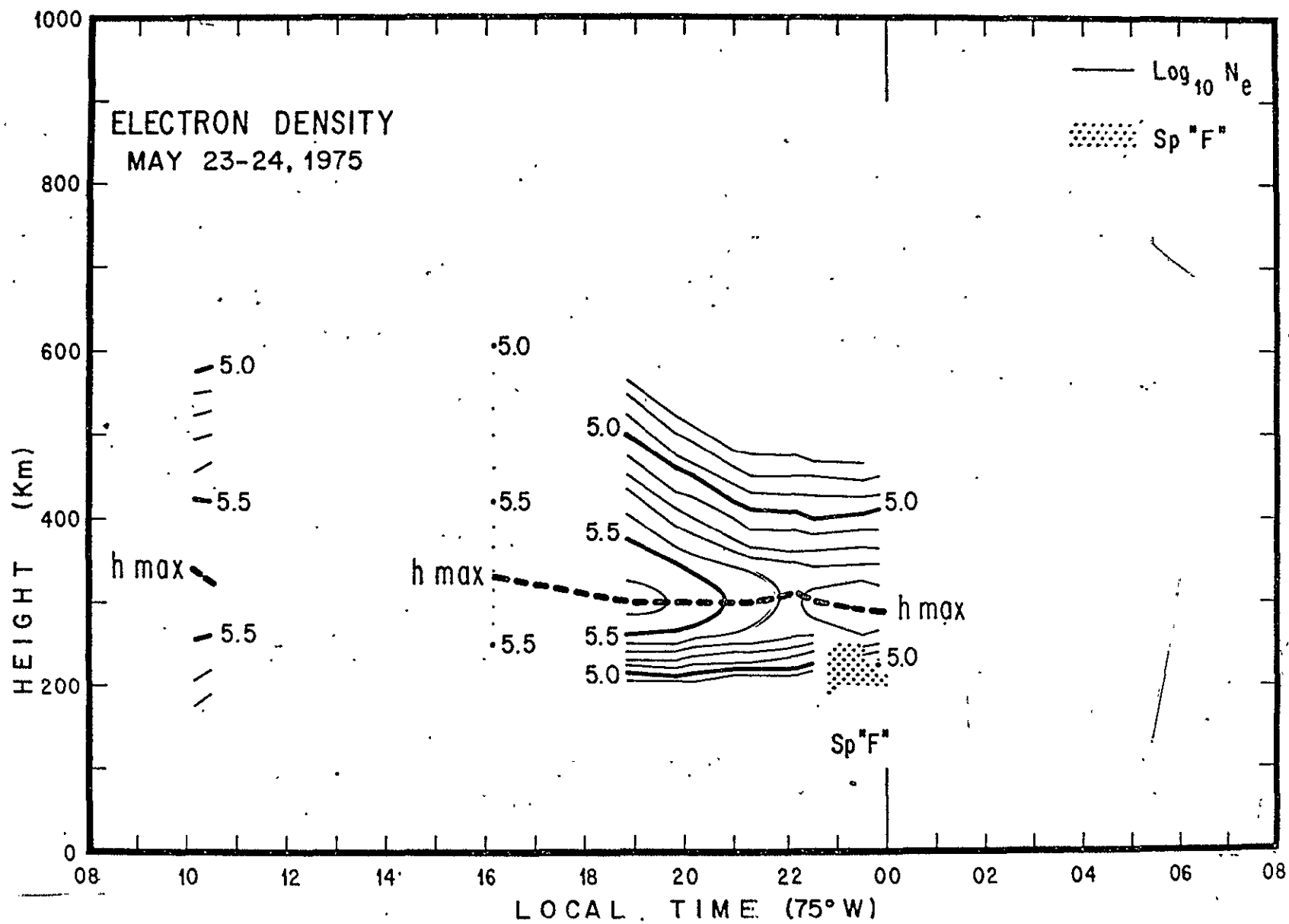


Fig. 5

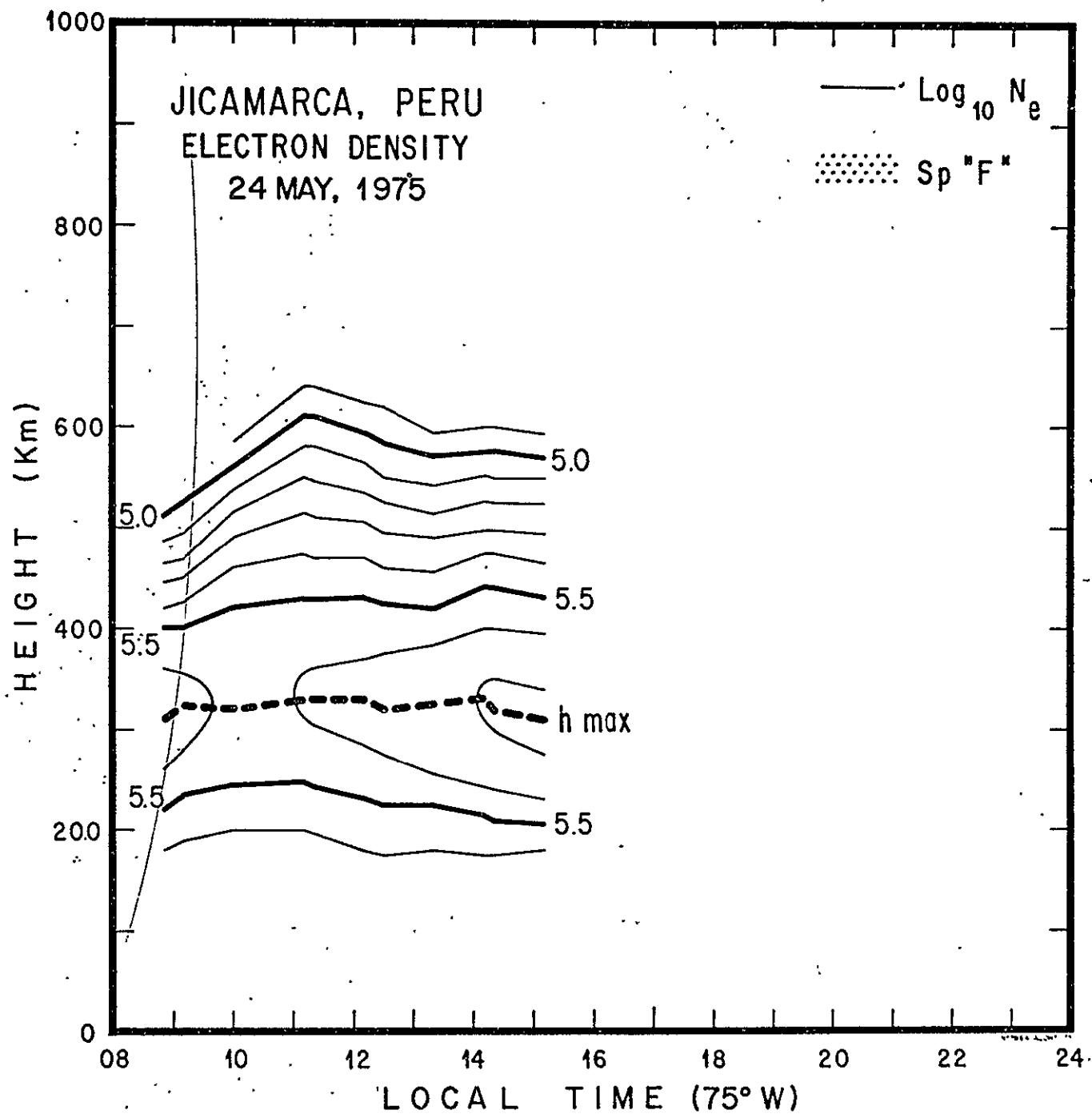


Fig. 6.

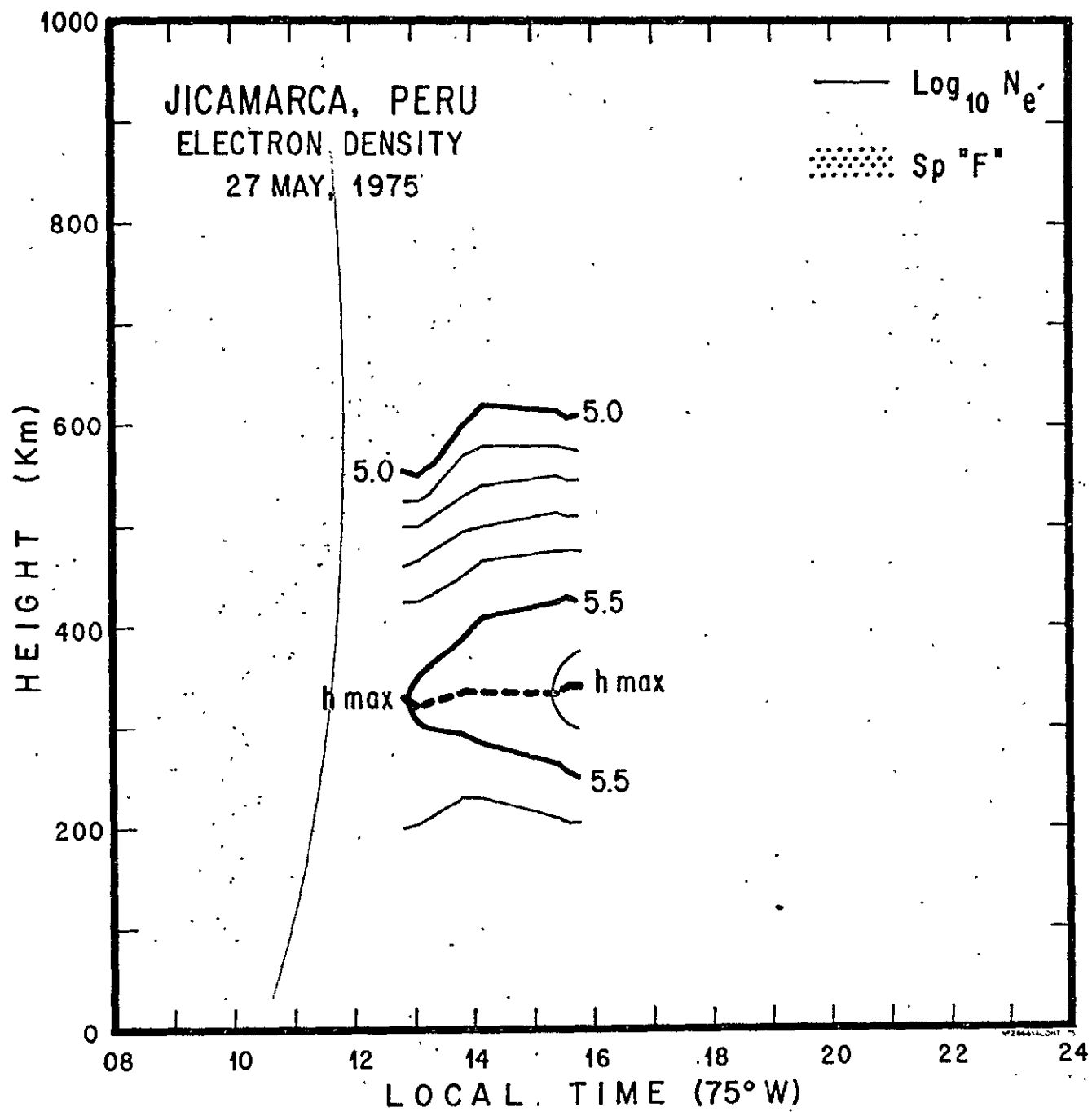


Fig. 7

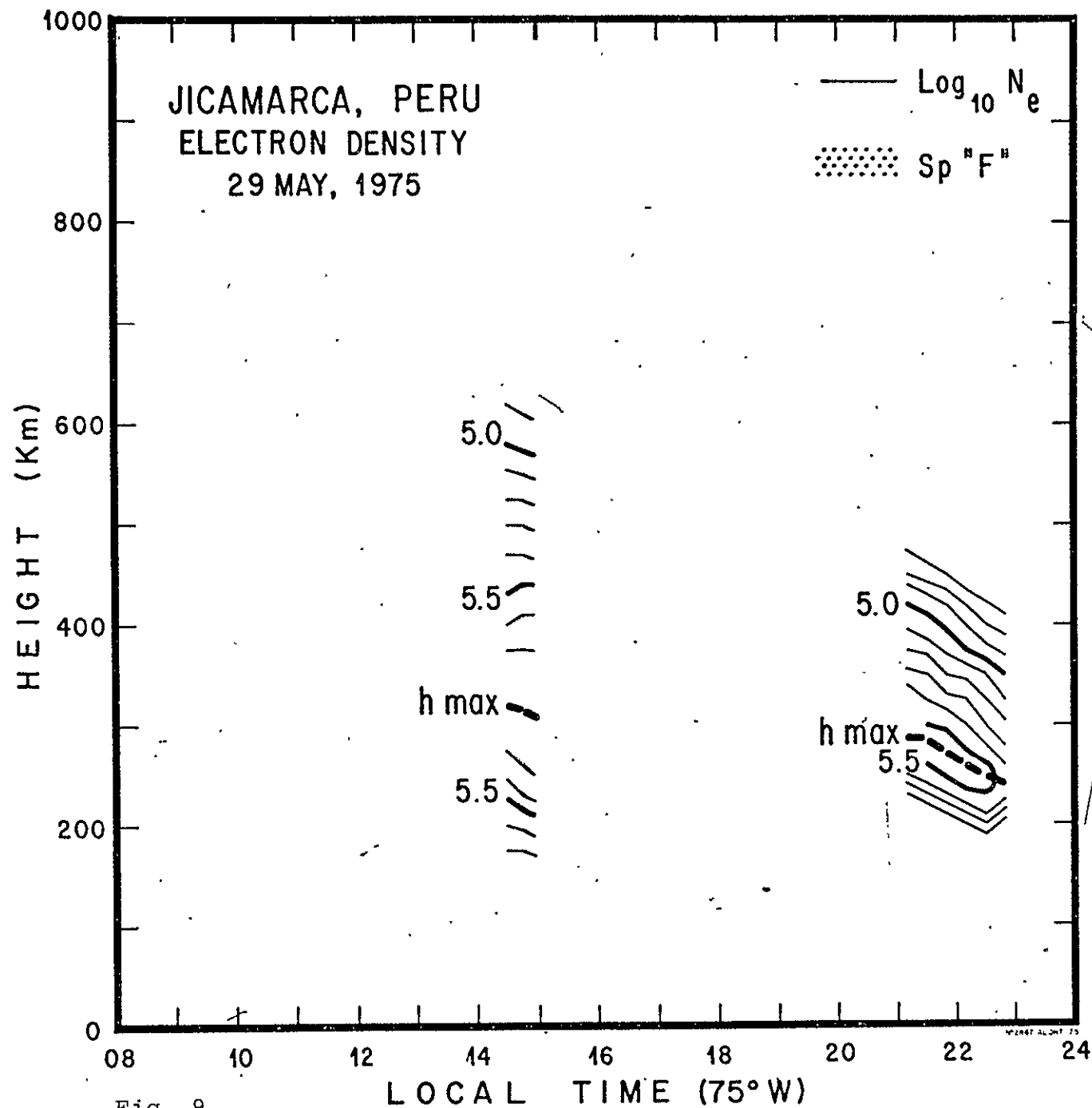


Fig. 9

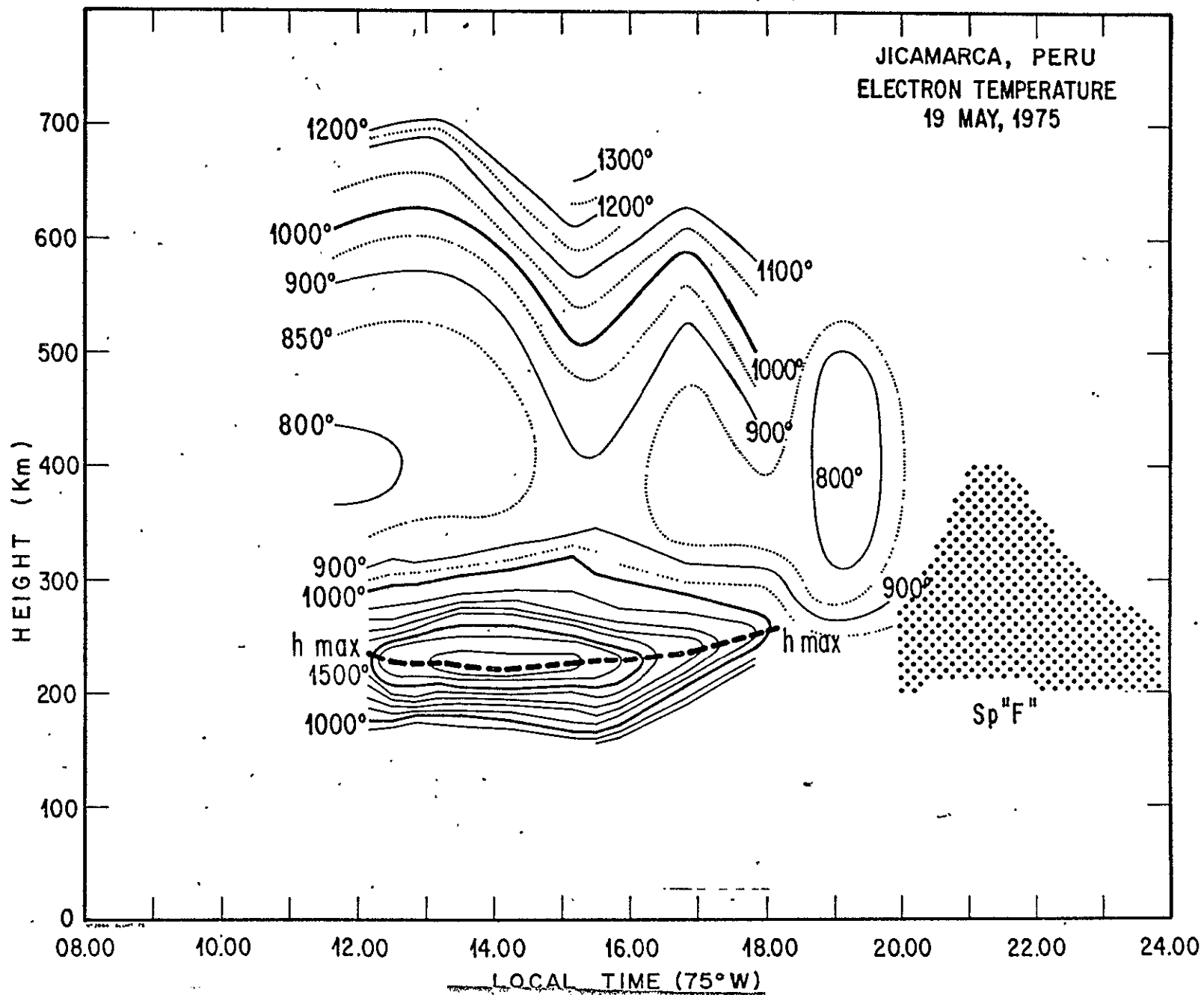


Fig. 10

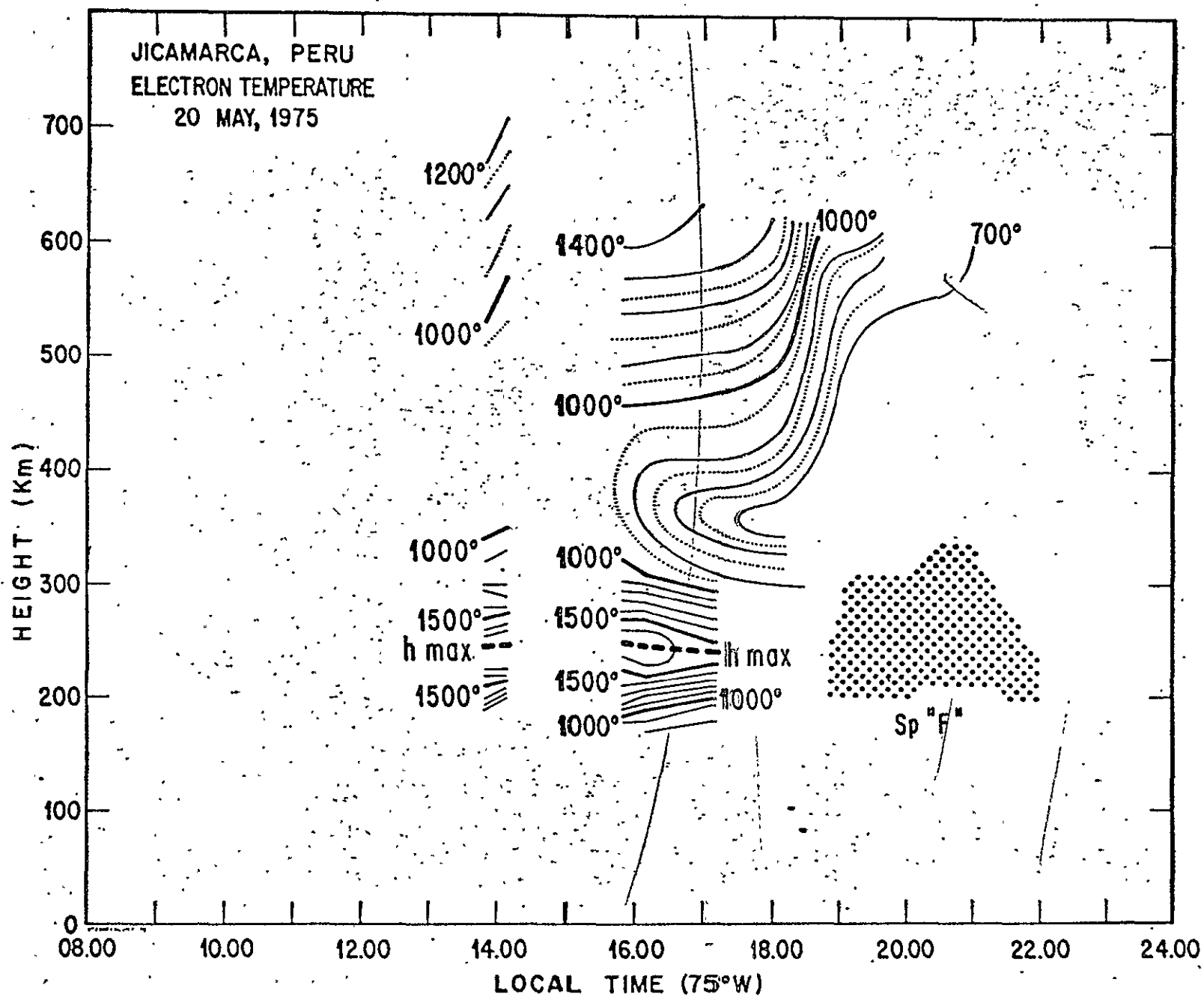


Fig. 11

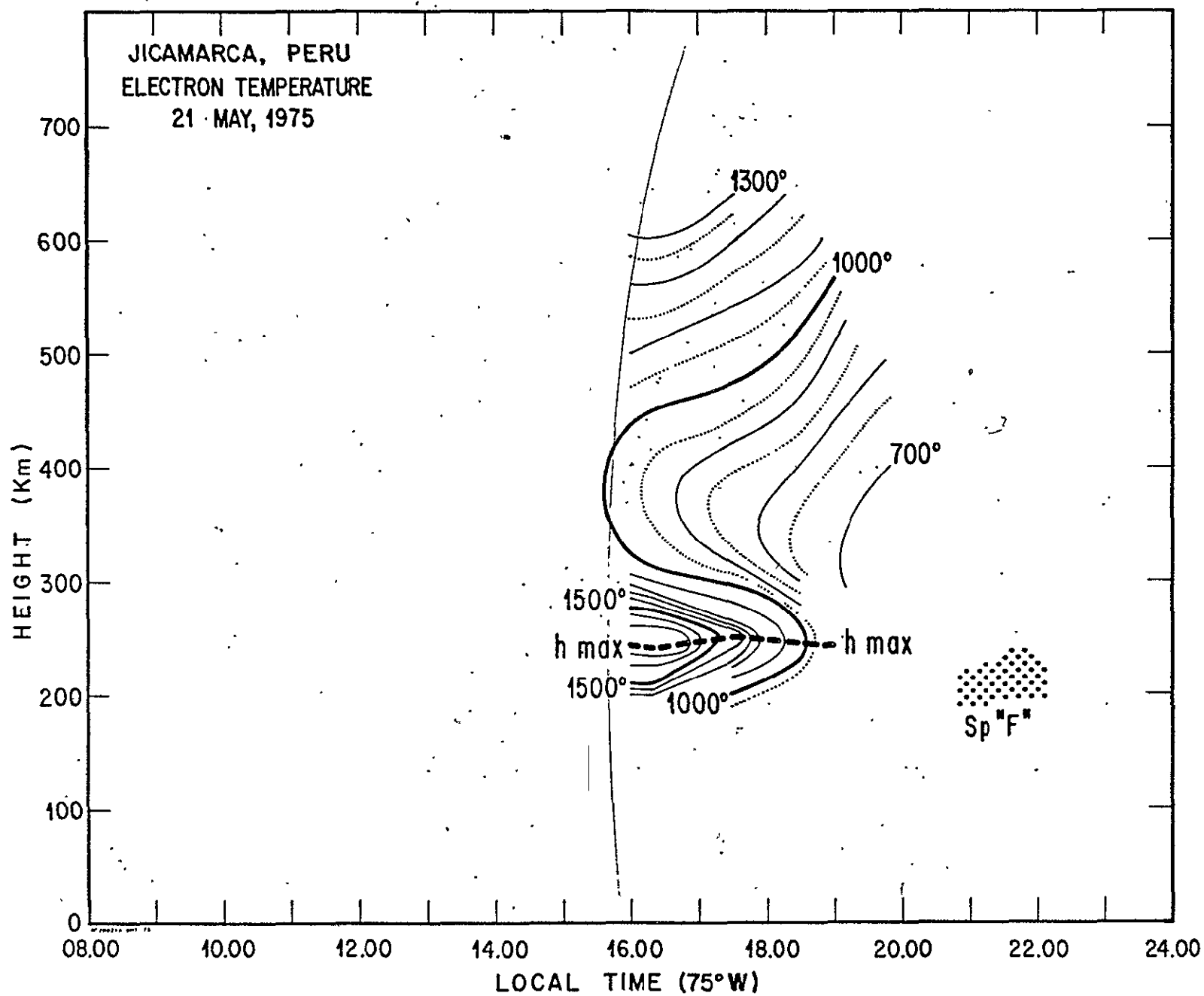


Fig. 12

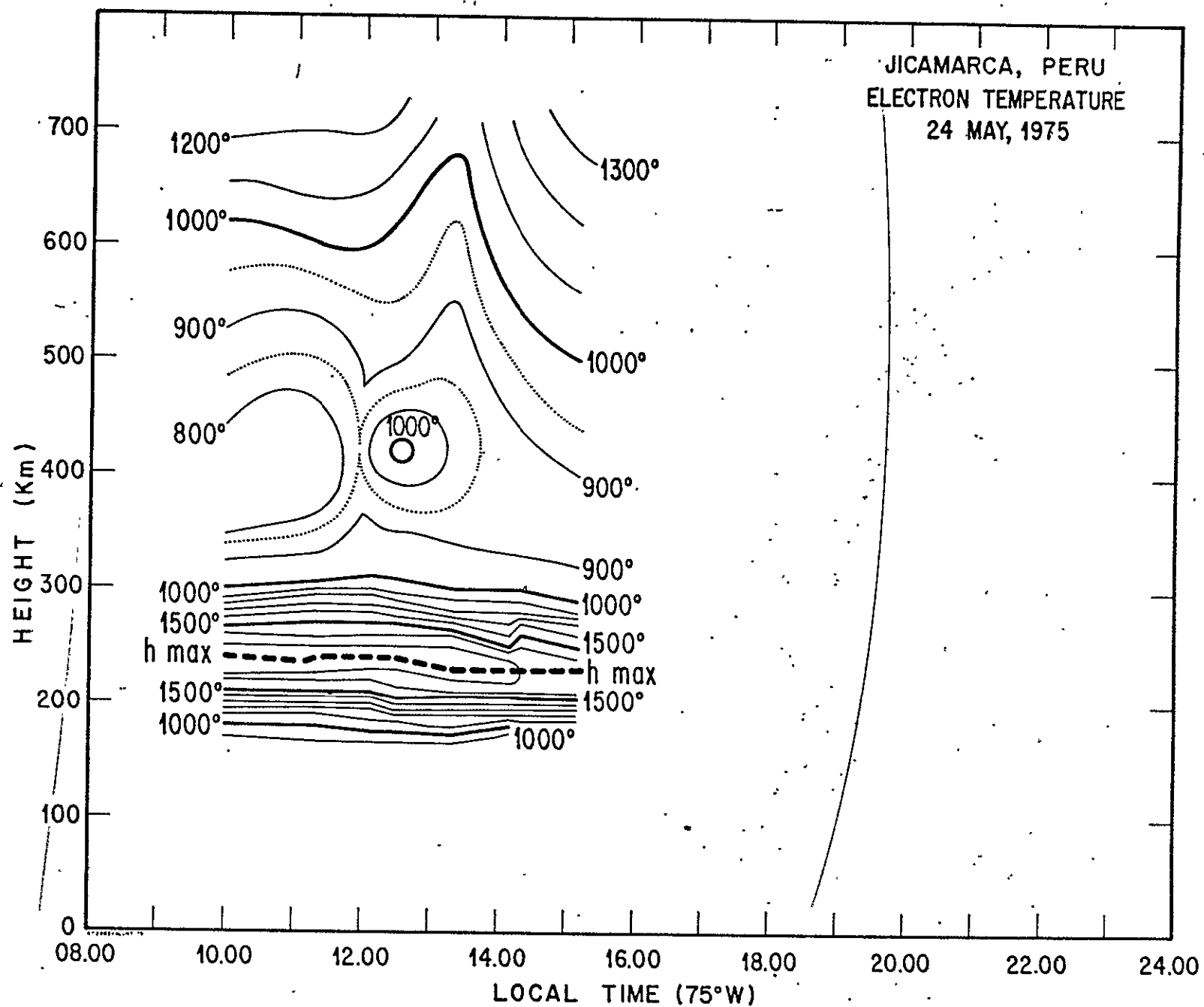


Fig. 13

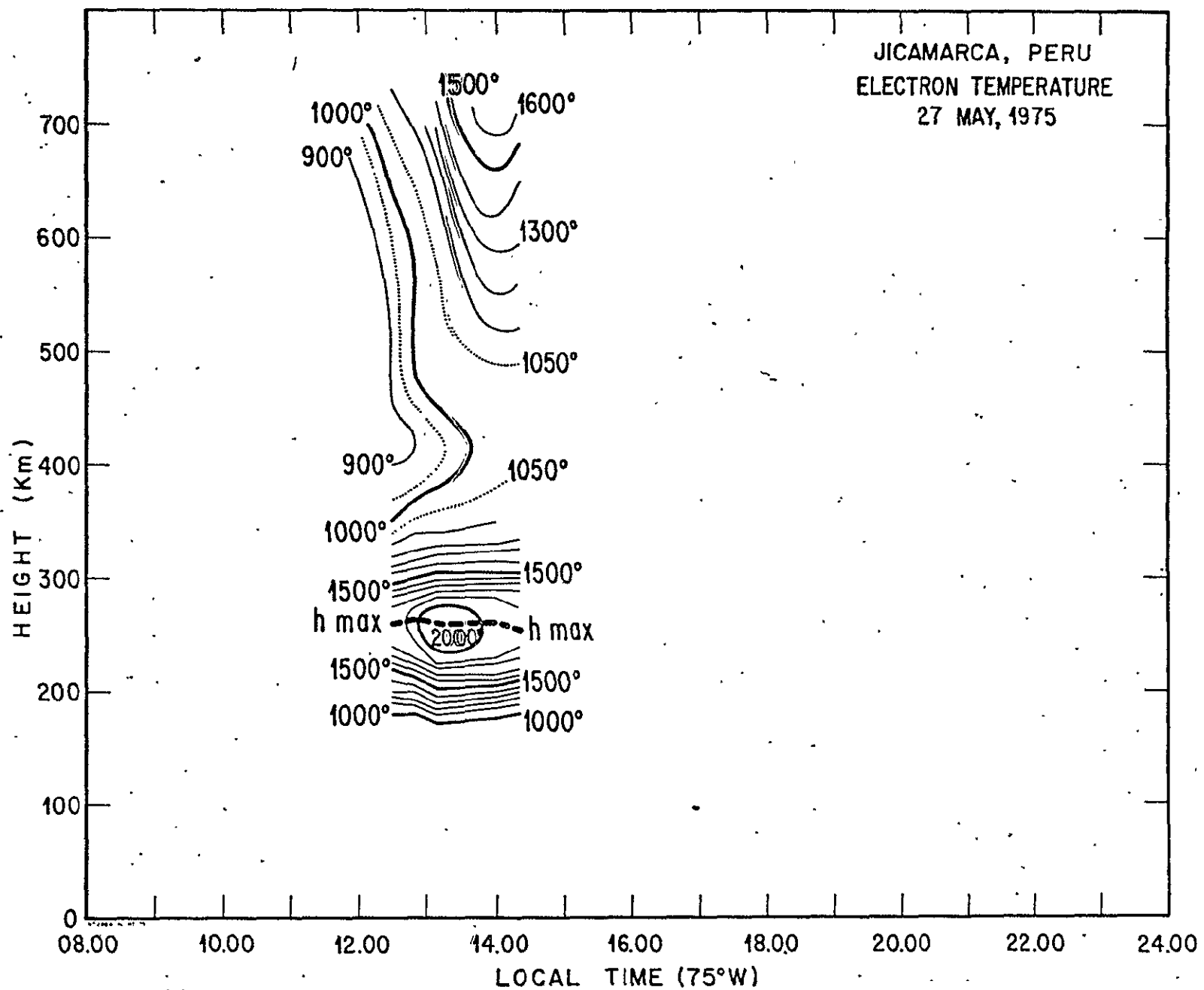


Fig. 14

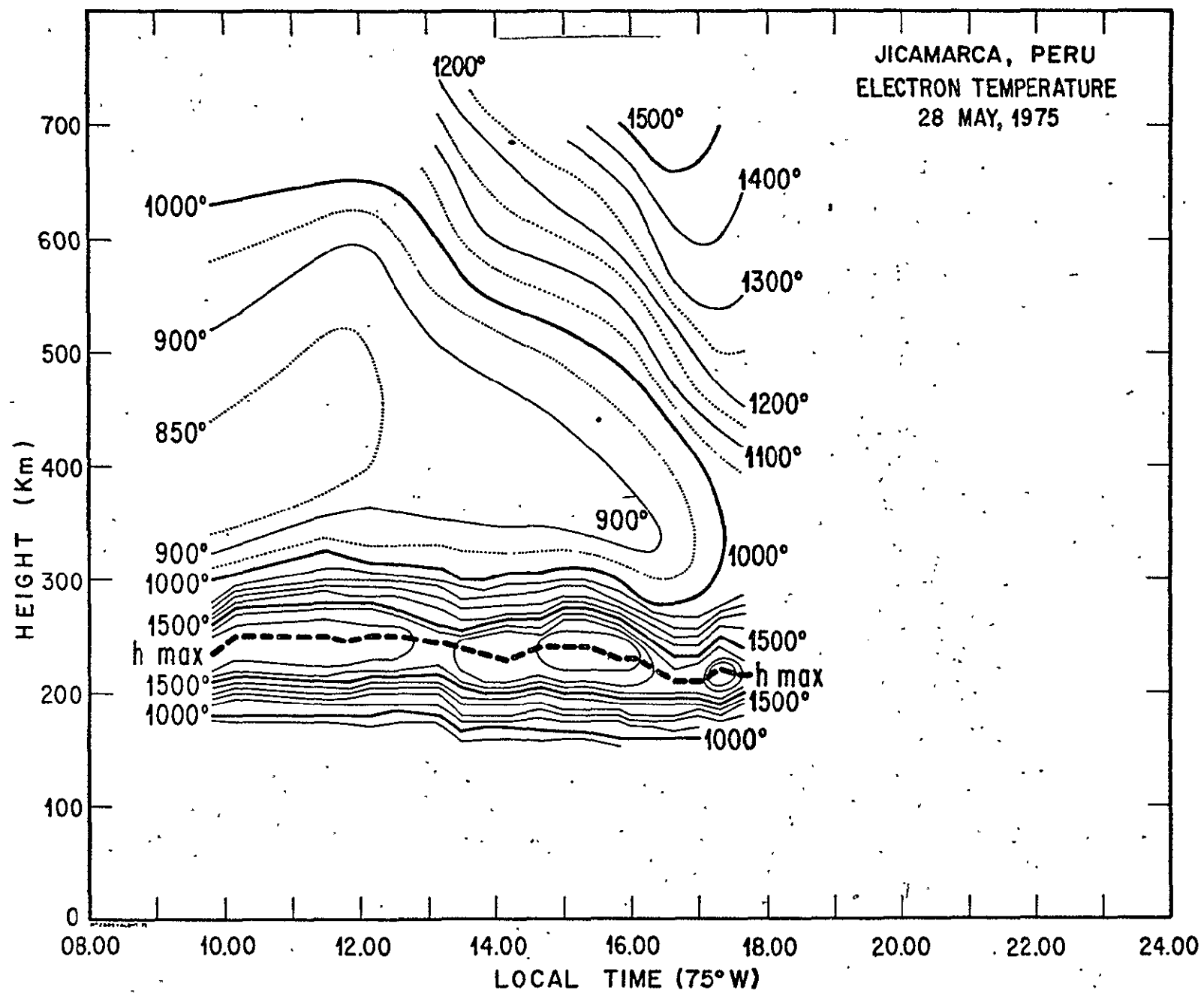


Fig. 15

APPENDIX B

VERTICAL DRIFT

FIGURE CAPTIONS

Fig. 16 to 21 Vertical drift velocities and Spread-F activity for the local times (75°W) and dates indicated.

Fig. 22 Composite of Figs. 16 to 21.

Fig. 23 to 26 Vertical drift velocities and Spread-F activity for the local times (75°W) and dates indicated.

~~Fig. 27 Composite of Figs. 23 to 26.~~

Fig. 28 to 32 Typical drift profiles for the times (75° W) and dates indicated as functions of height.

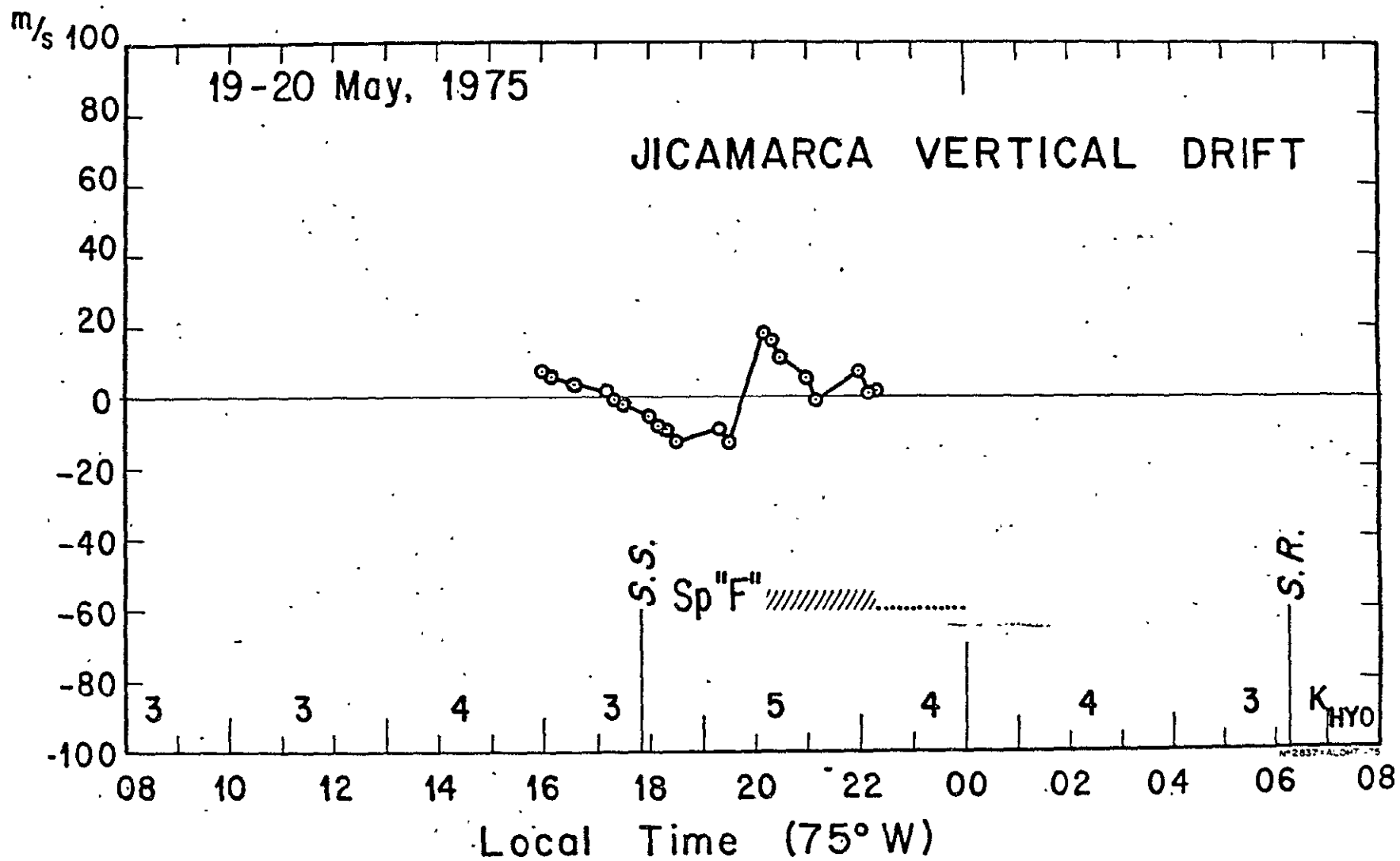


Fig. 16

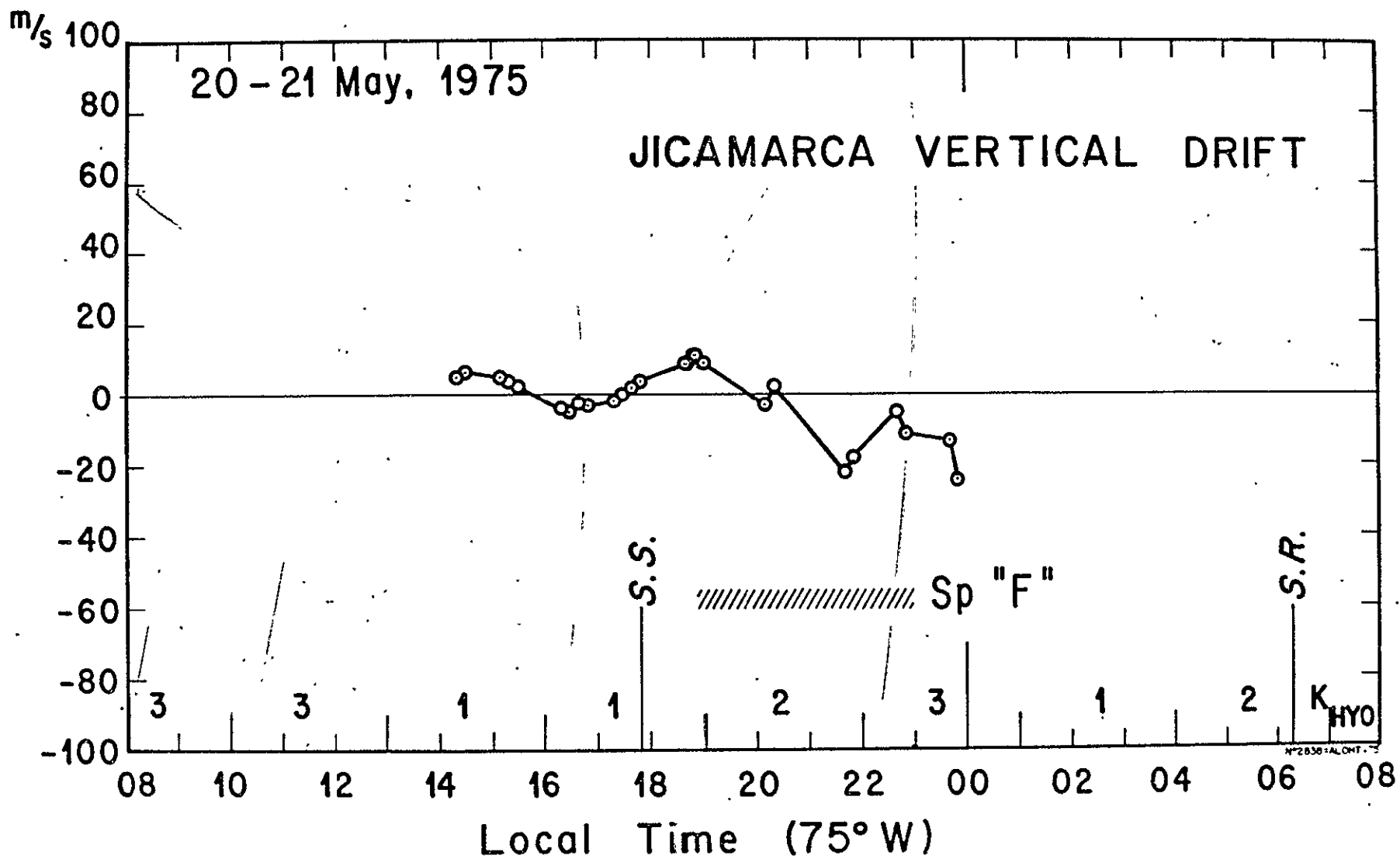


Fig. 17

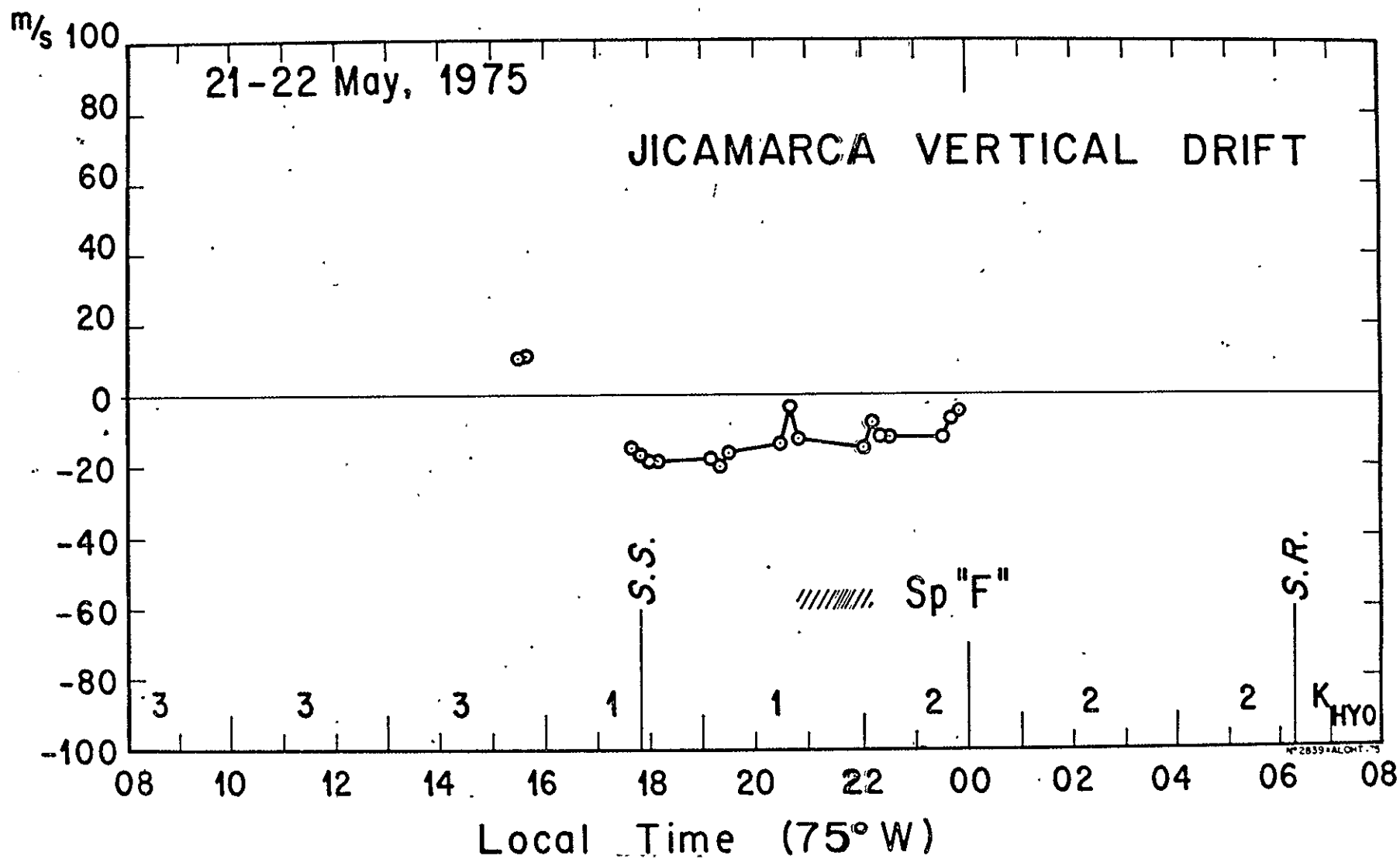


Fig. 18

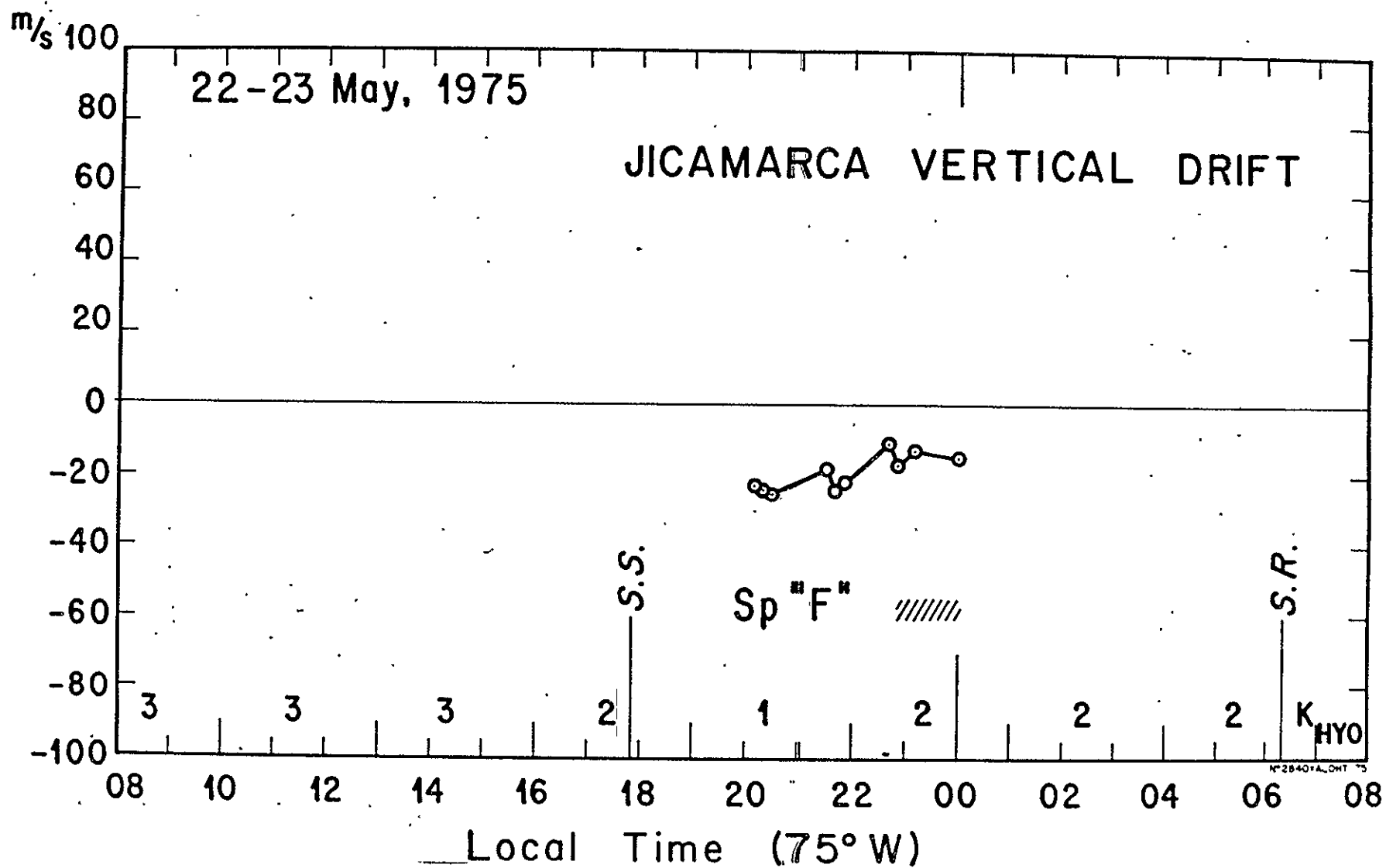


Fig. 19

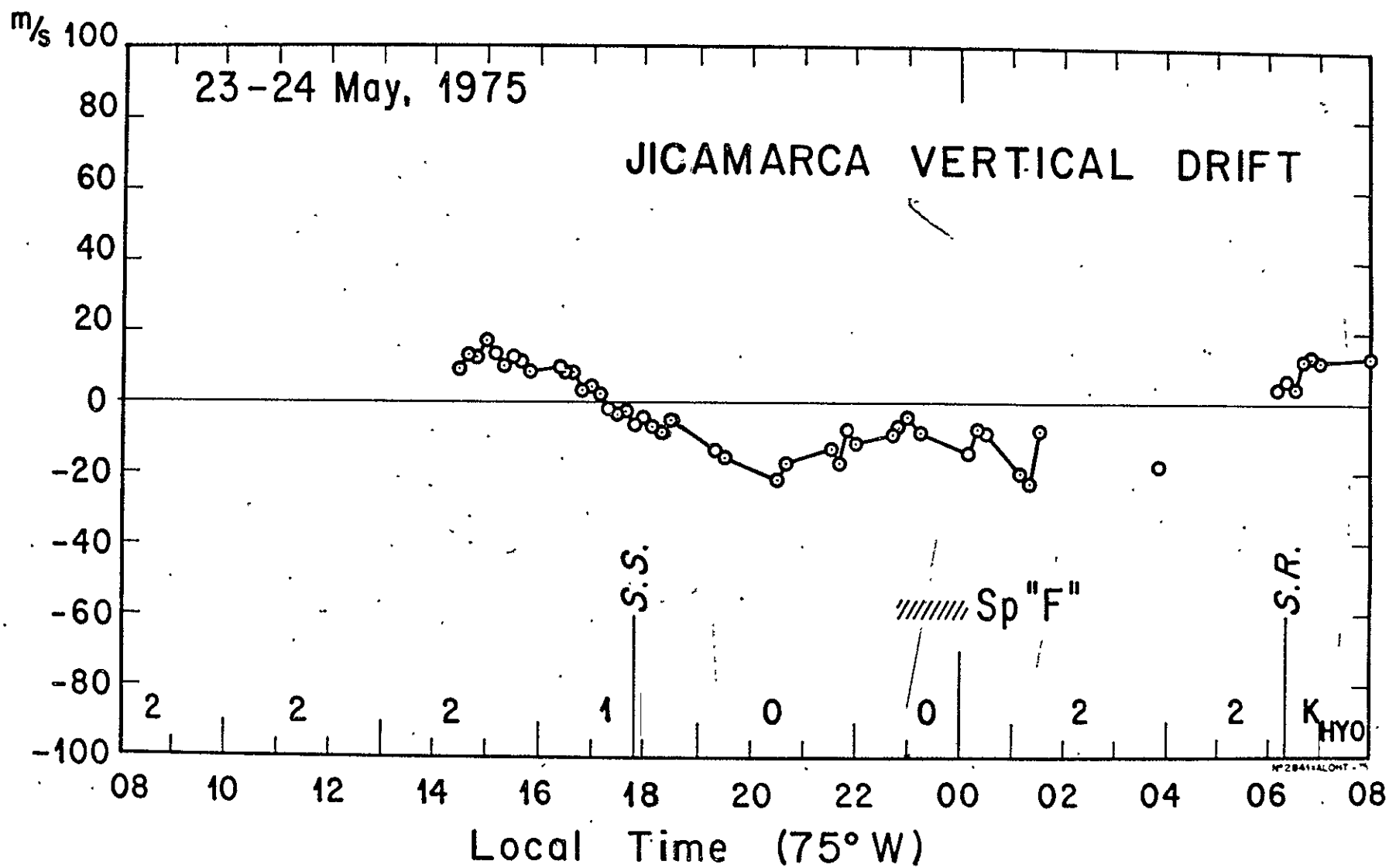


Fig. 20

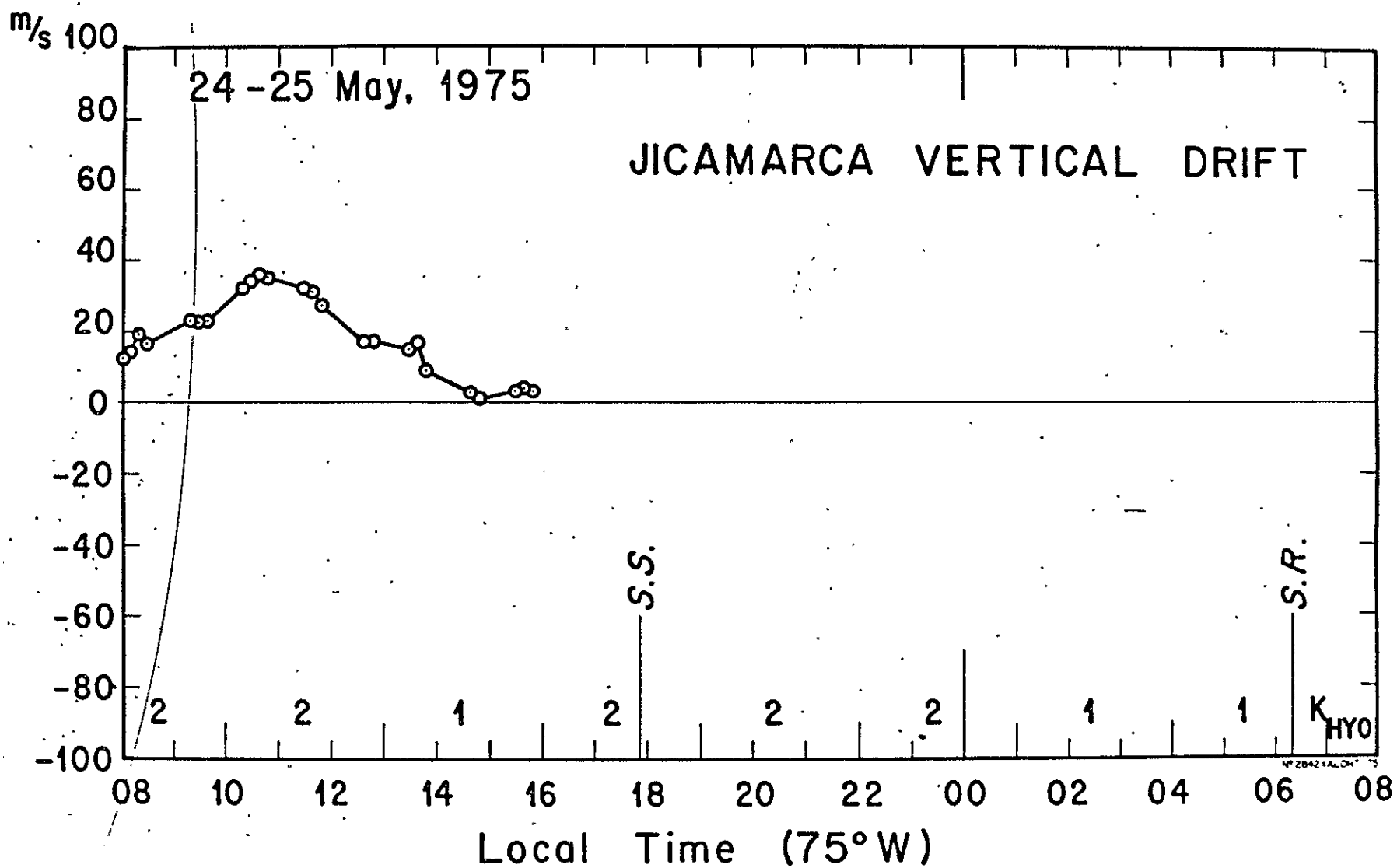


Fig. 21

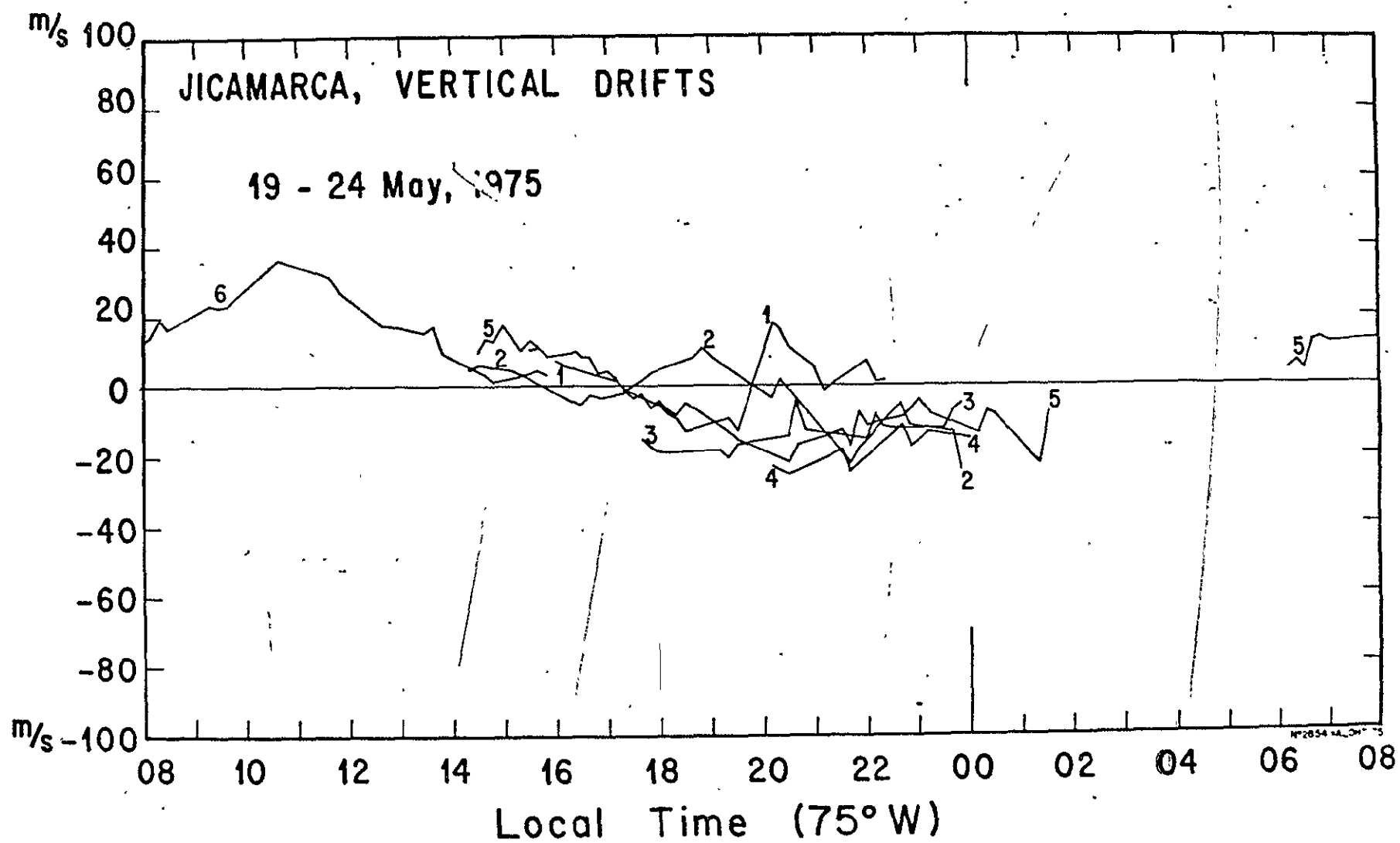


Fig. 22

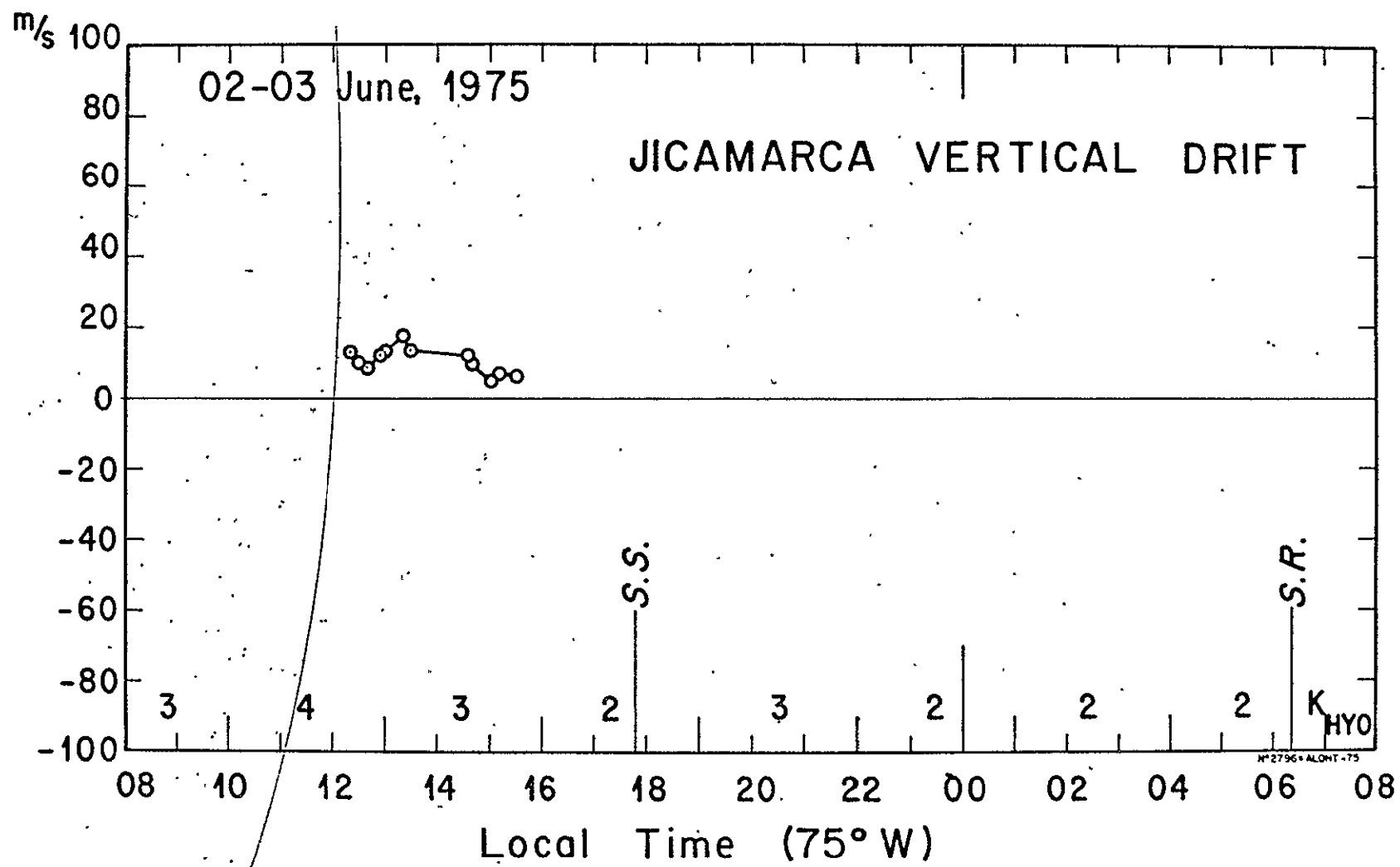


Fig. 23

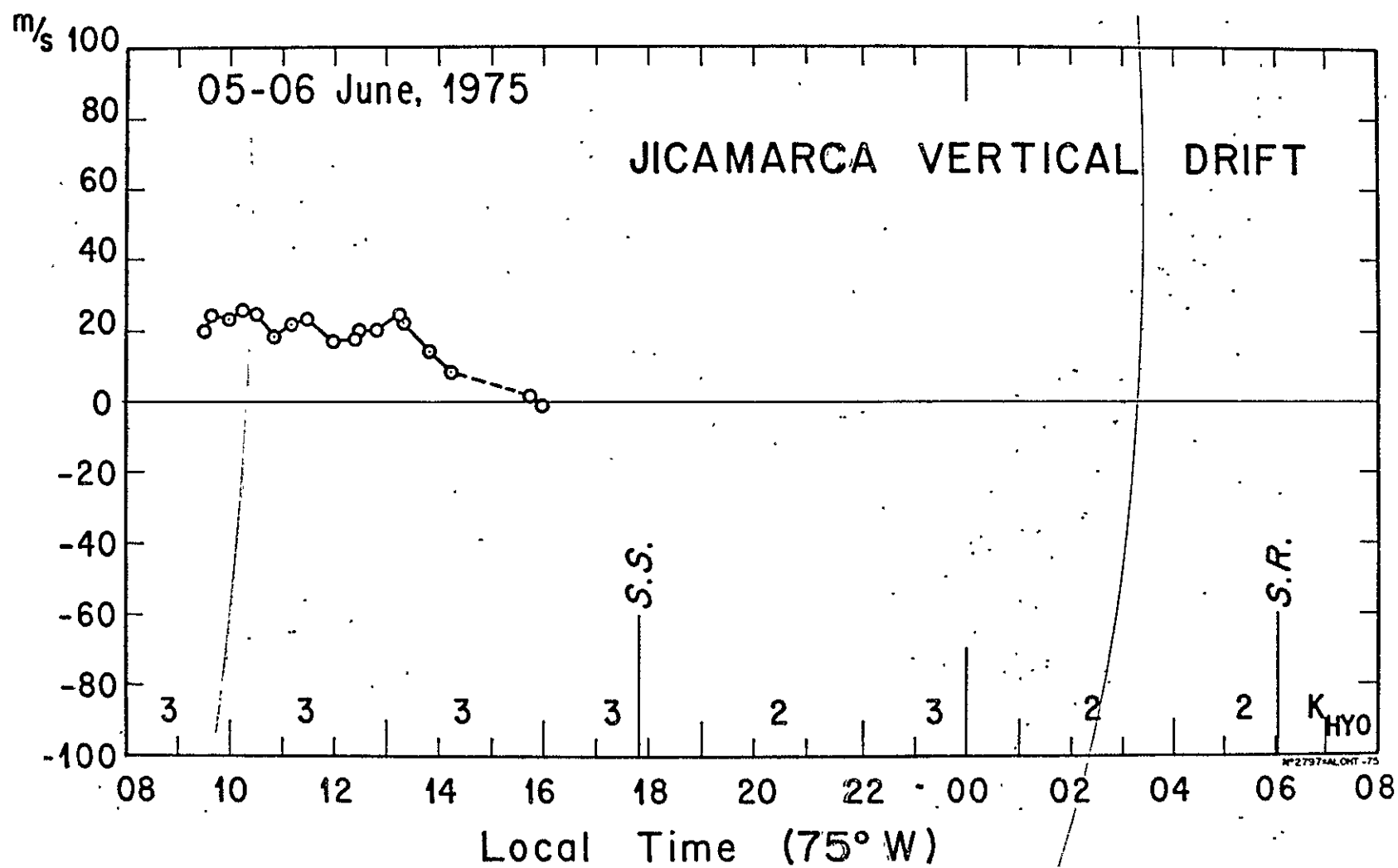


Fig. 24

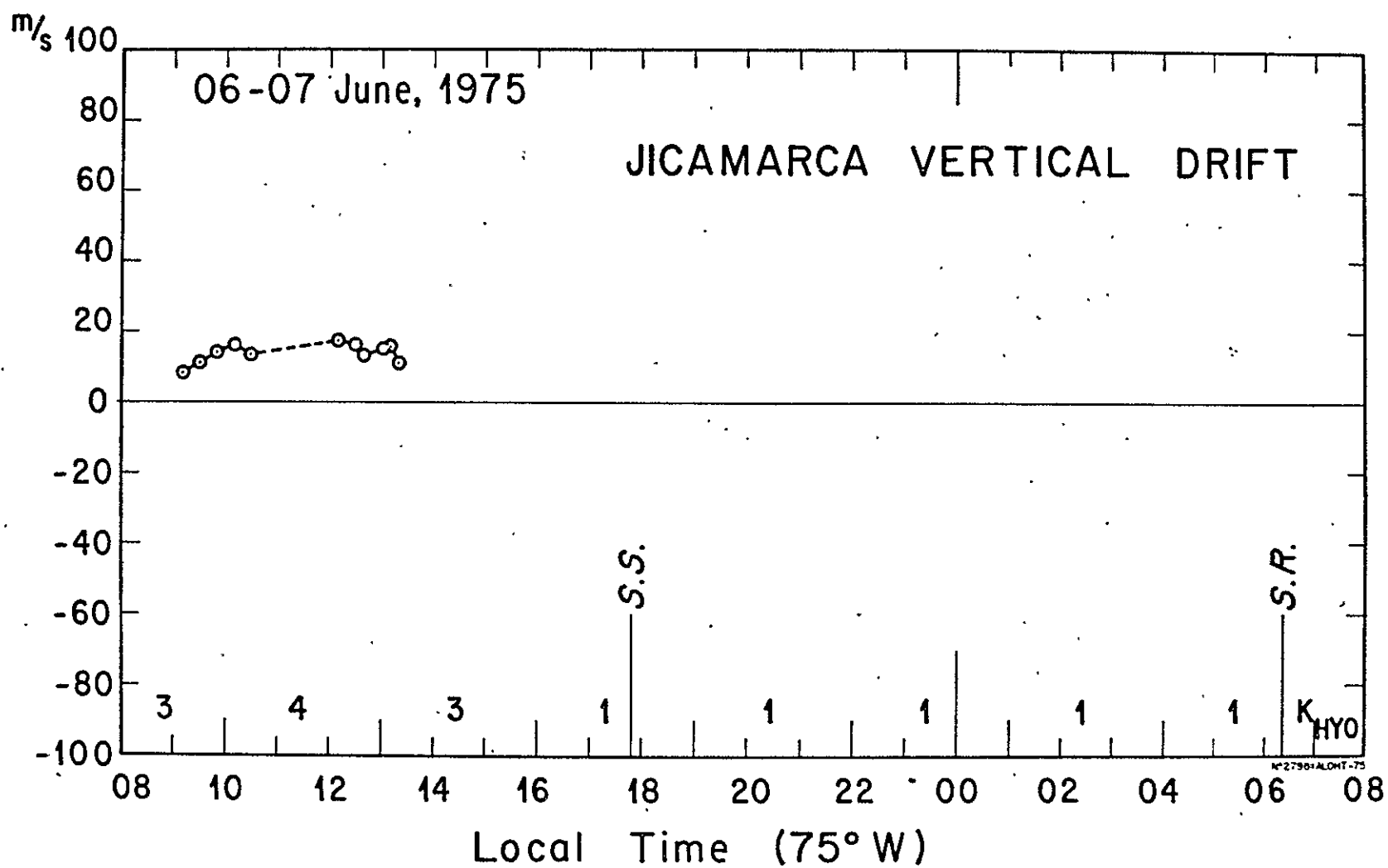


Fig. 25

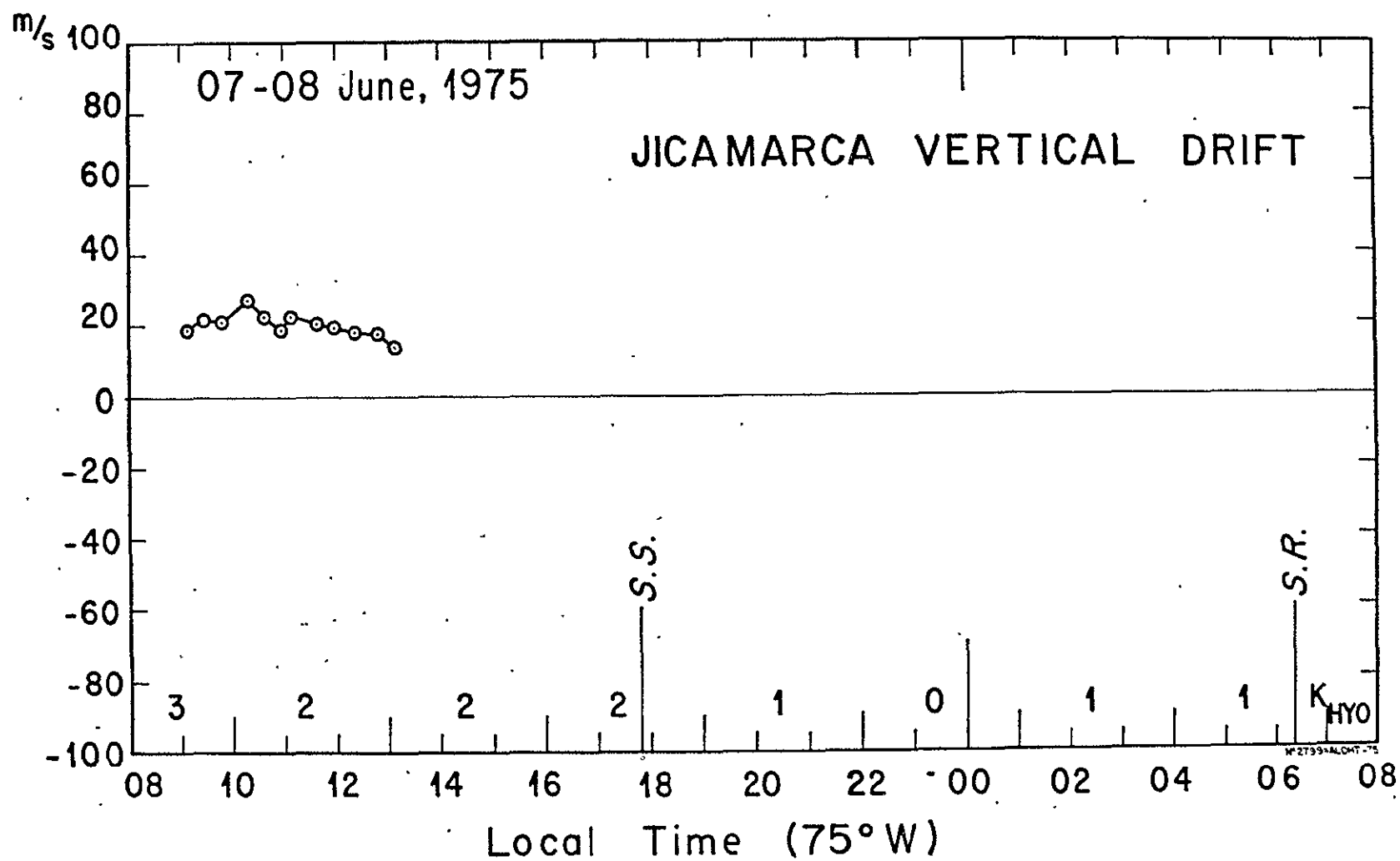
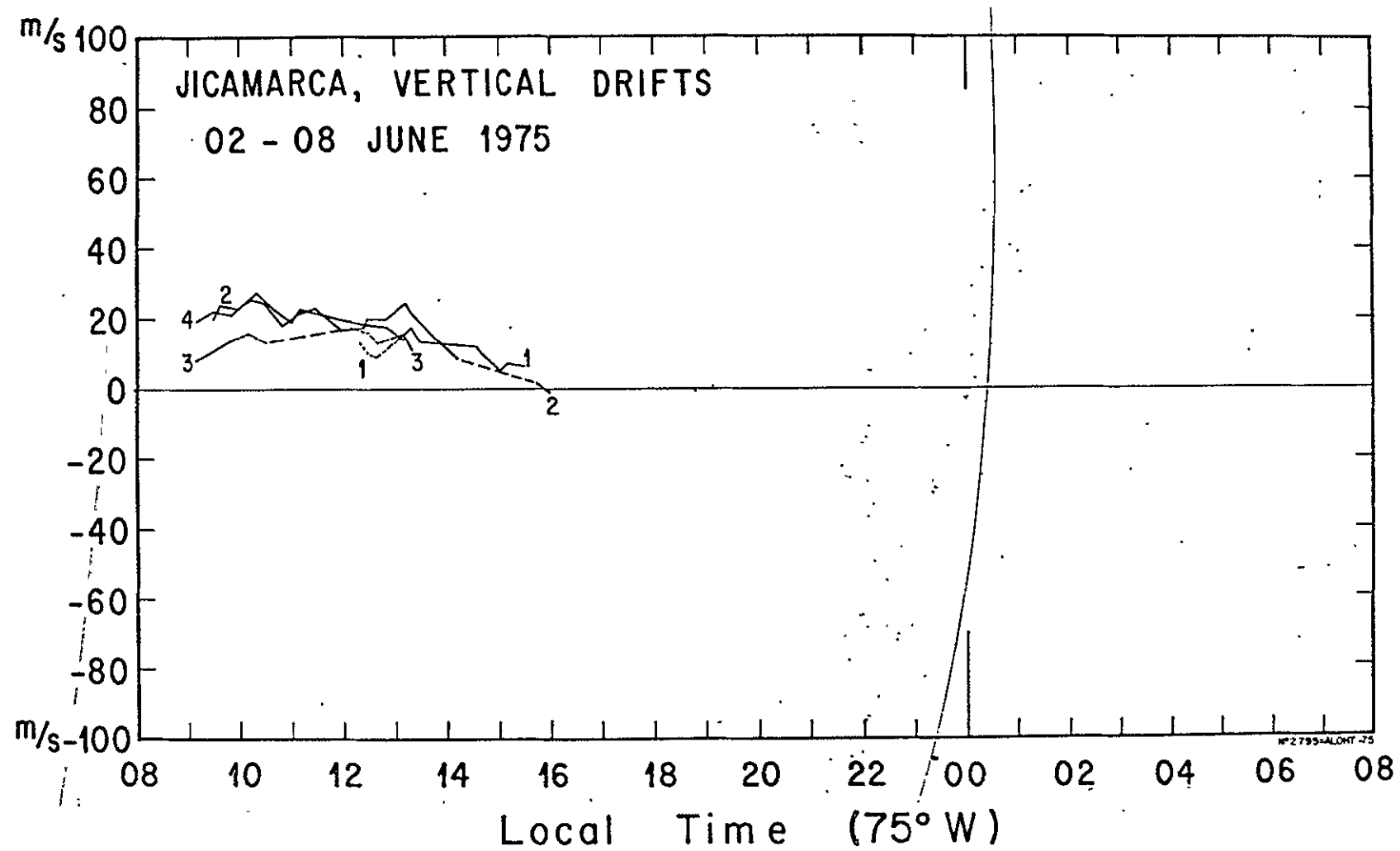
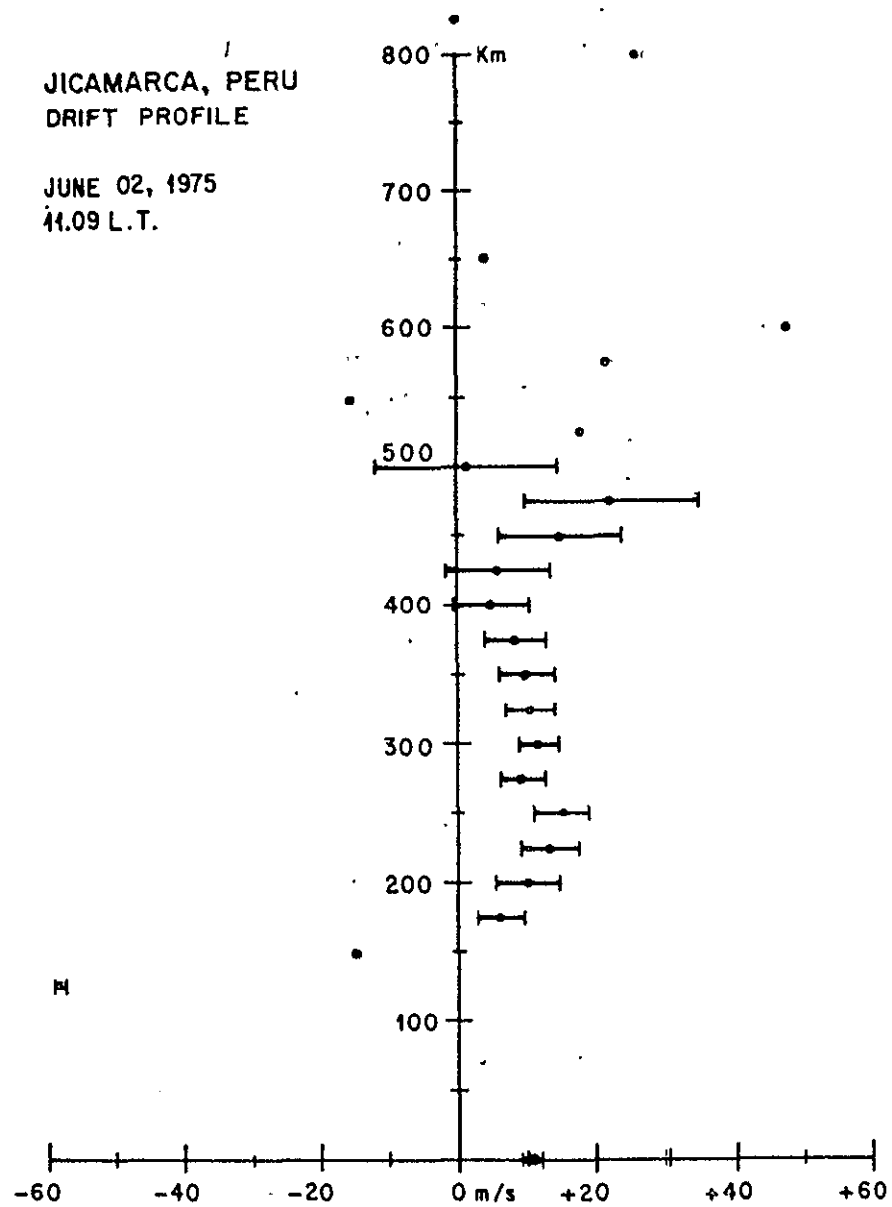


Fig. 26



JICAMARCA, PERU
DRIFT PROFILE

JUNE 02, 1975
11.09 L.T.



Nº 2,824

Fig. 28

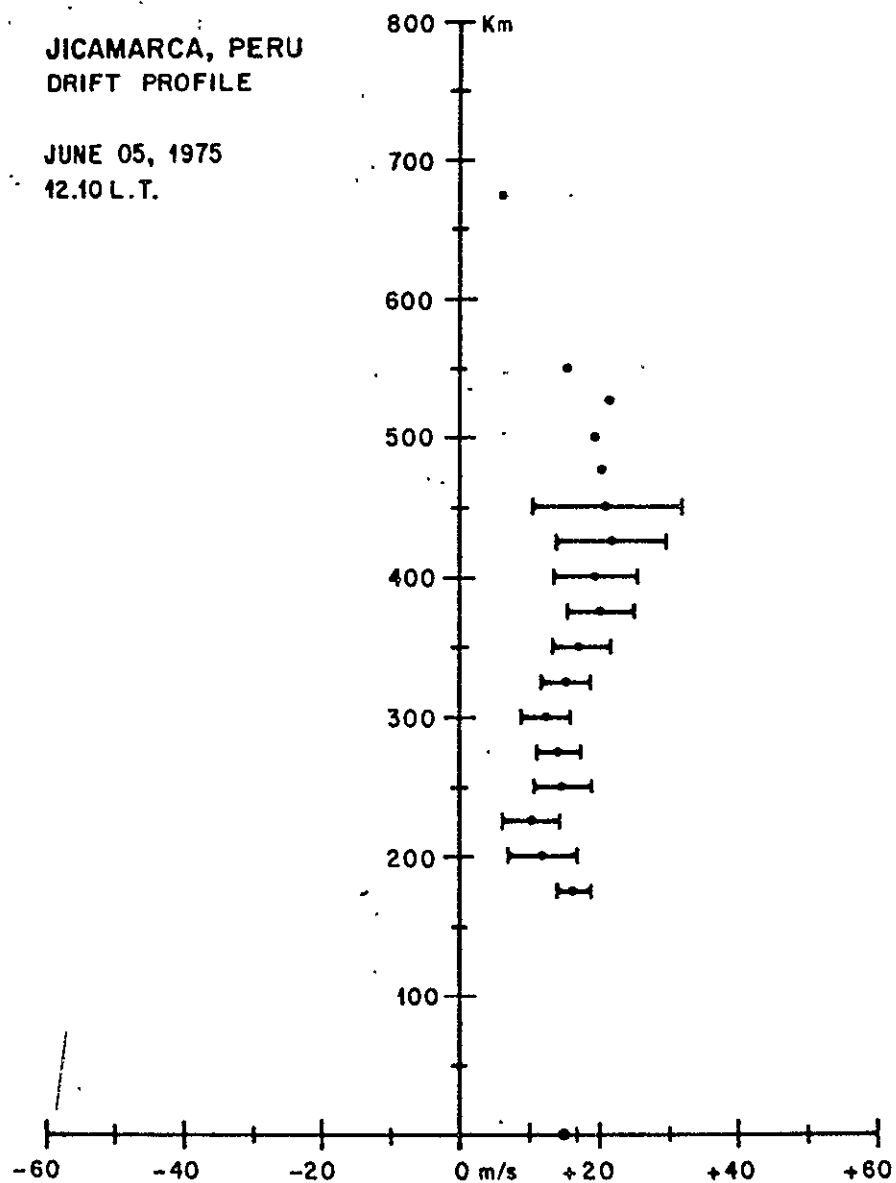


Fig. 29

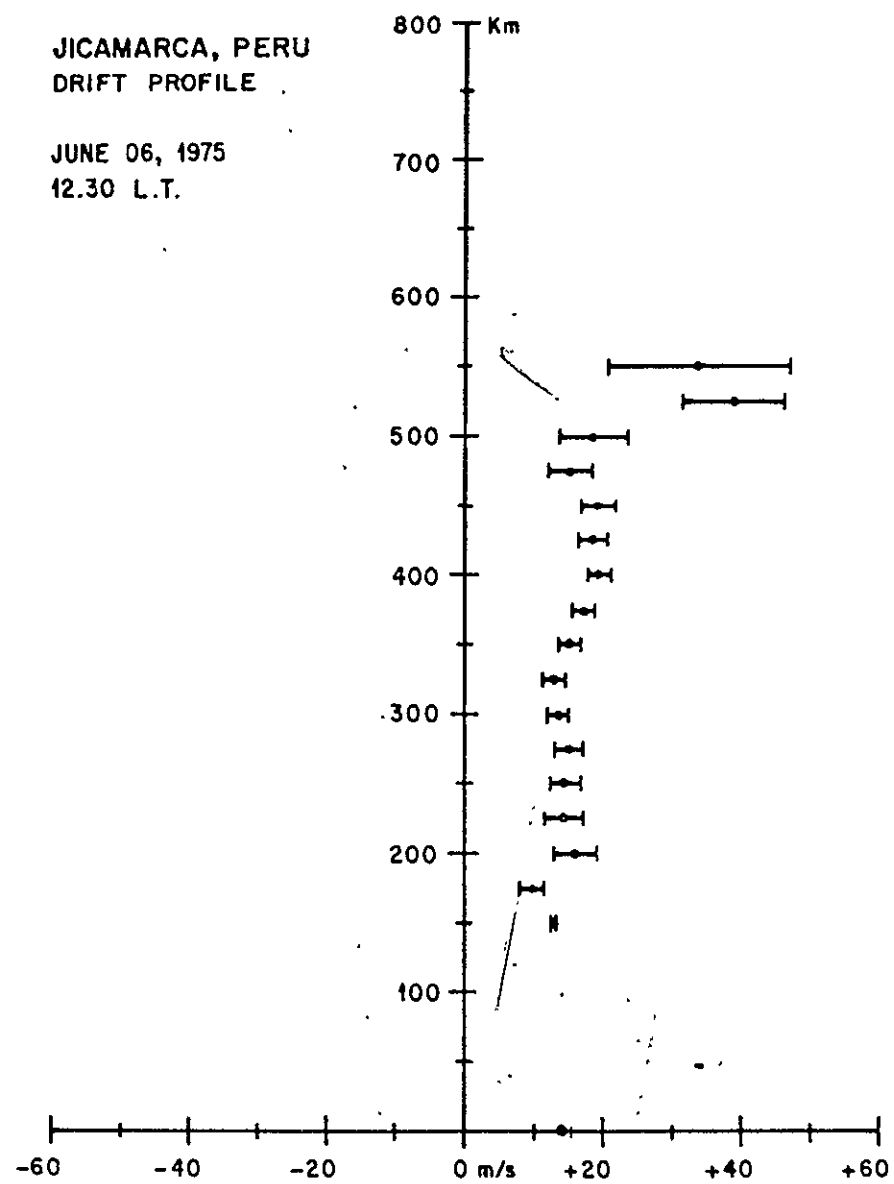


Fig. 30

JICAMARCA, PERU
 DRIFT PROFILE
 11.07 Rocket Launch Time
 JUNE 07, 1975
 11.00 L.T.

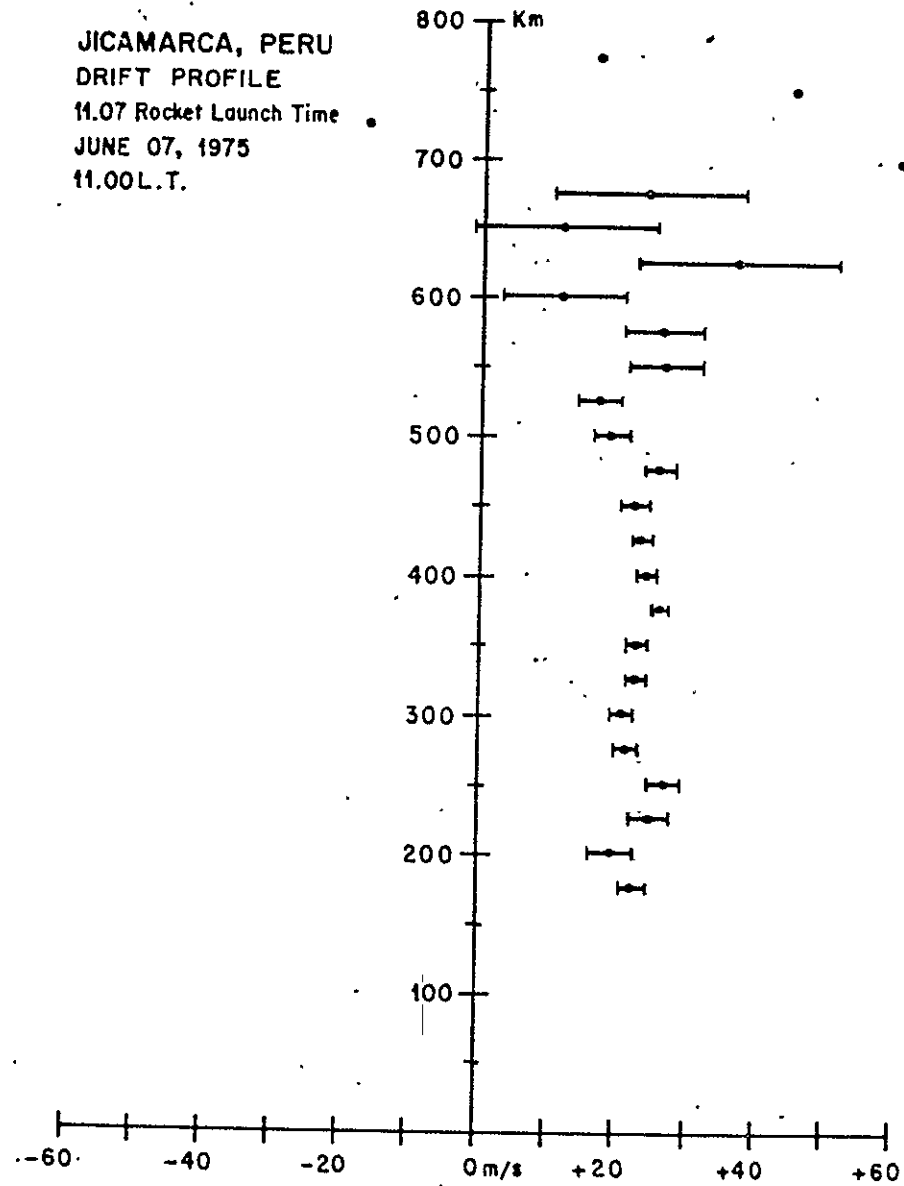


Fig. 31

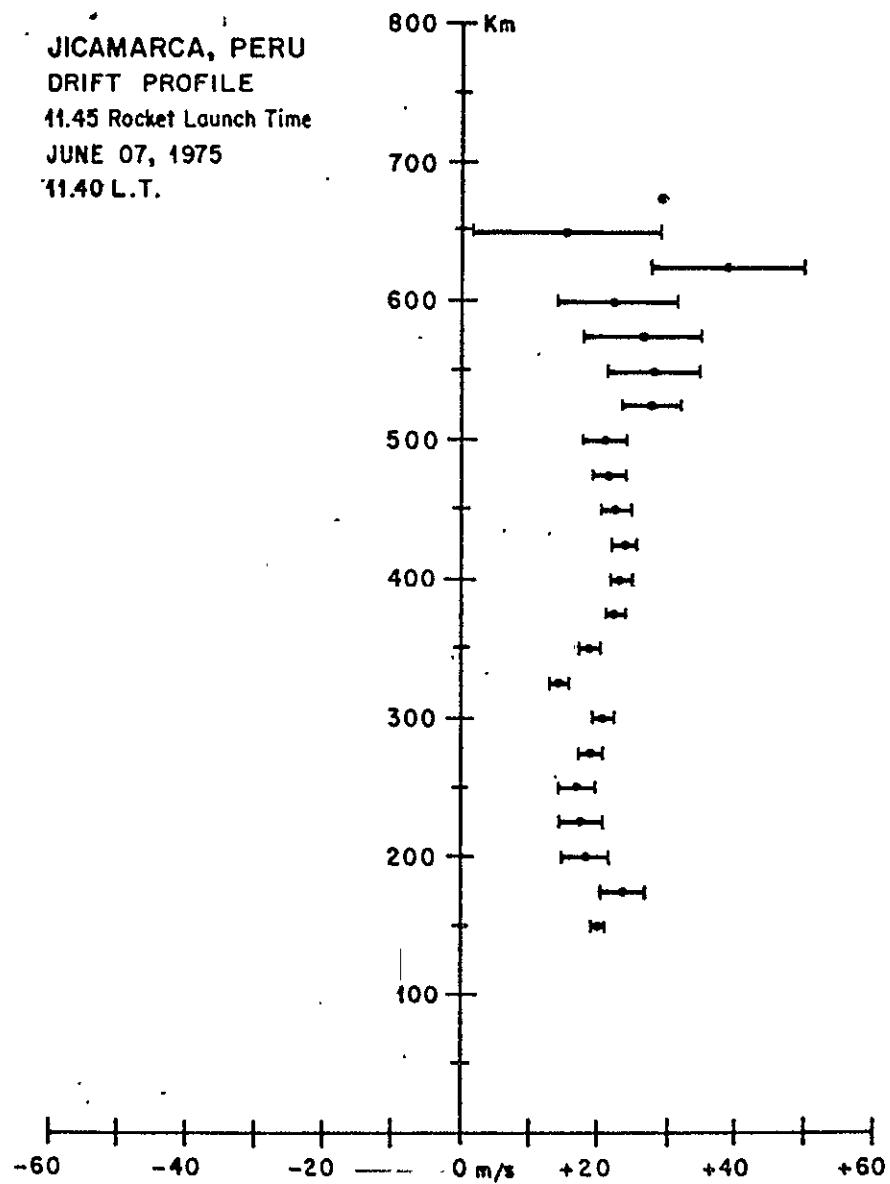


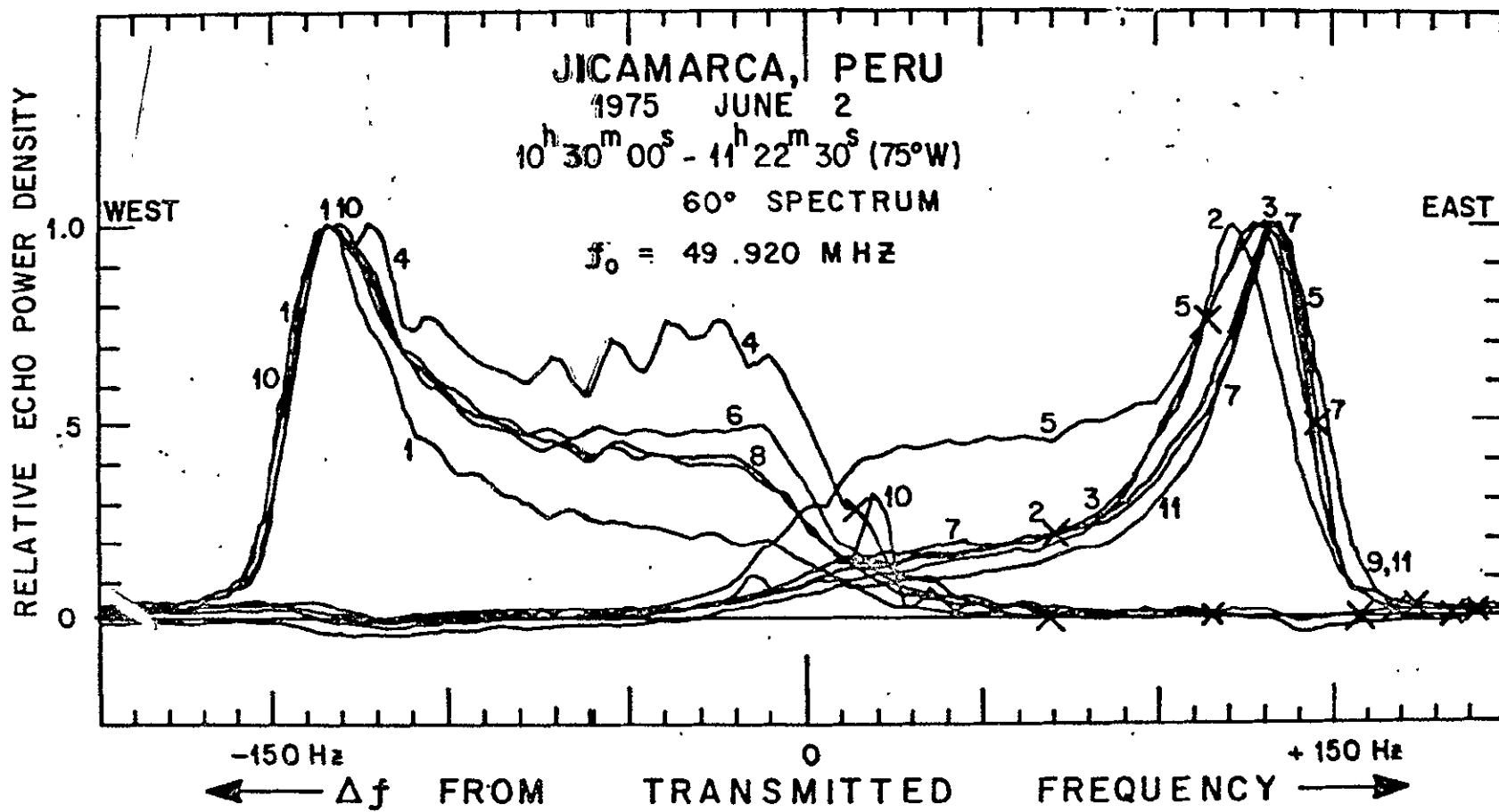
Fig. 32

APPENDIX C

ELECTROJET. RELATIVE ECHO POWER DENSITY

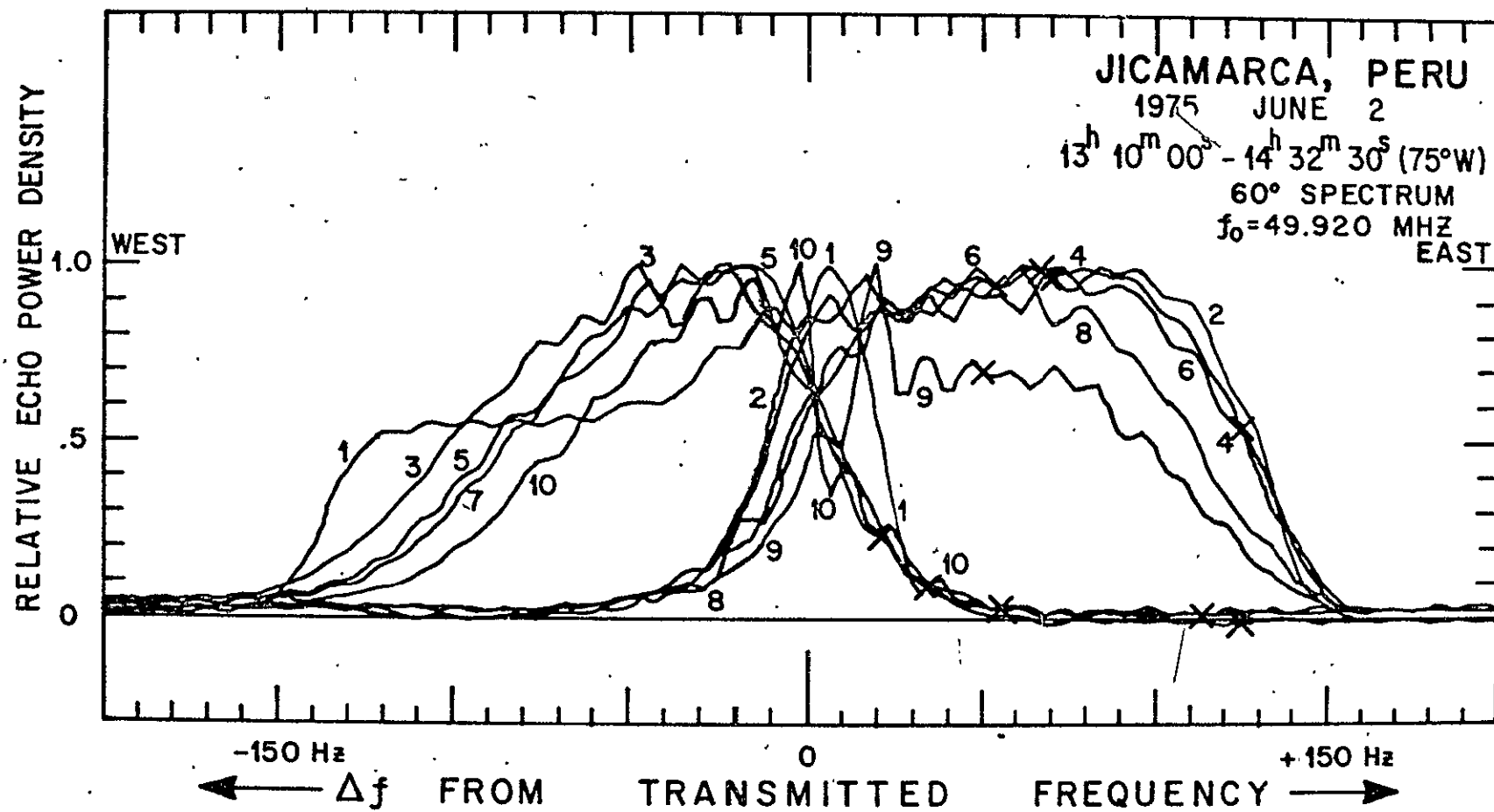
FIGURE CAPTIONS

Fig. 33 to 67 Composite of relative echo power density versus frequency deviation for the times (75°W) and dates indicated.



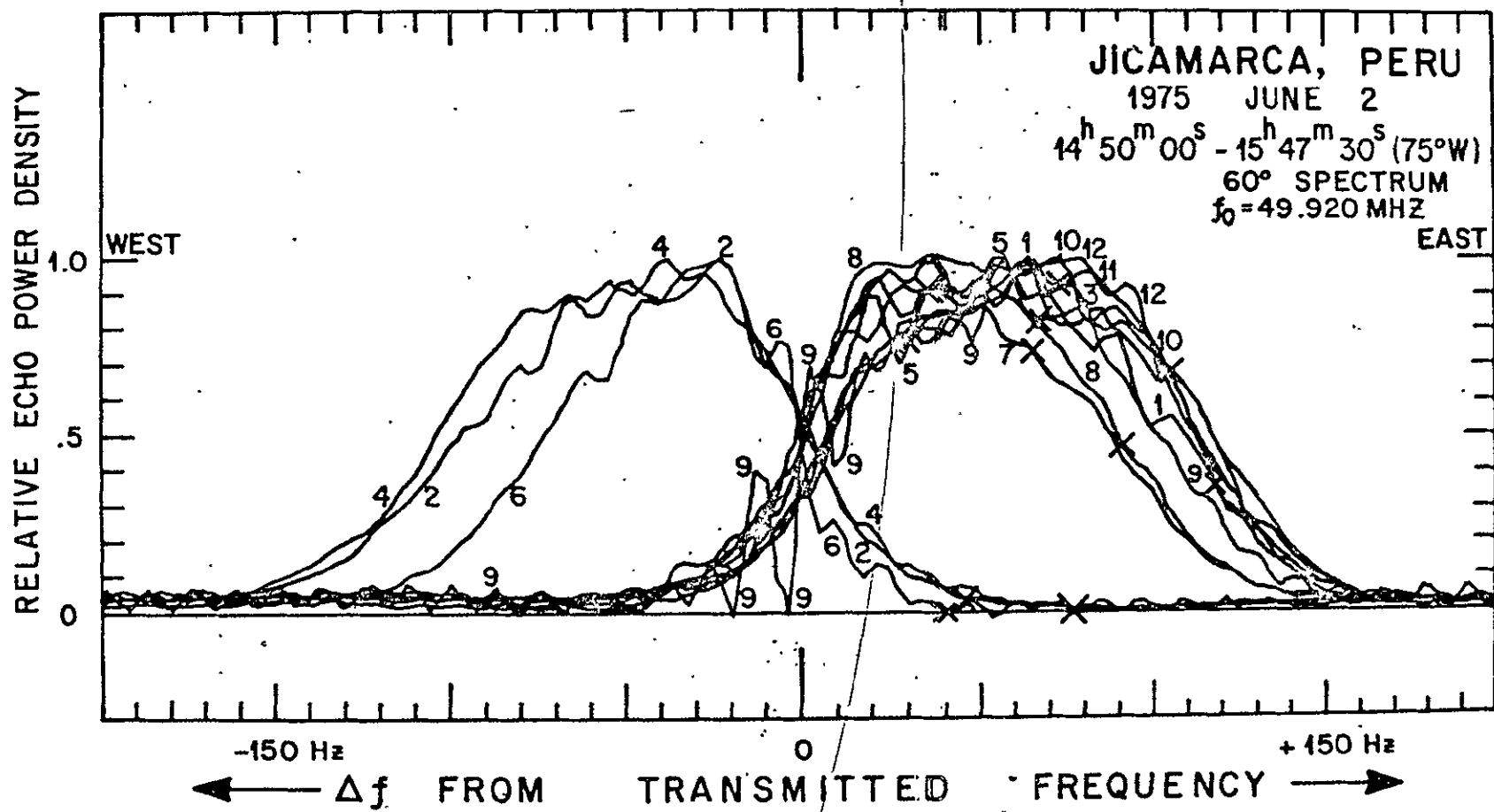
N°2766
ALONT.75

Fig. 33



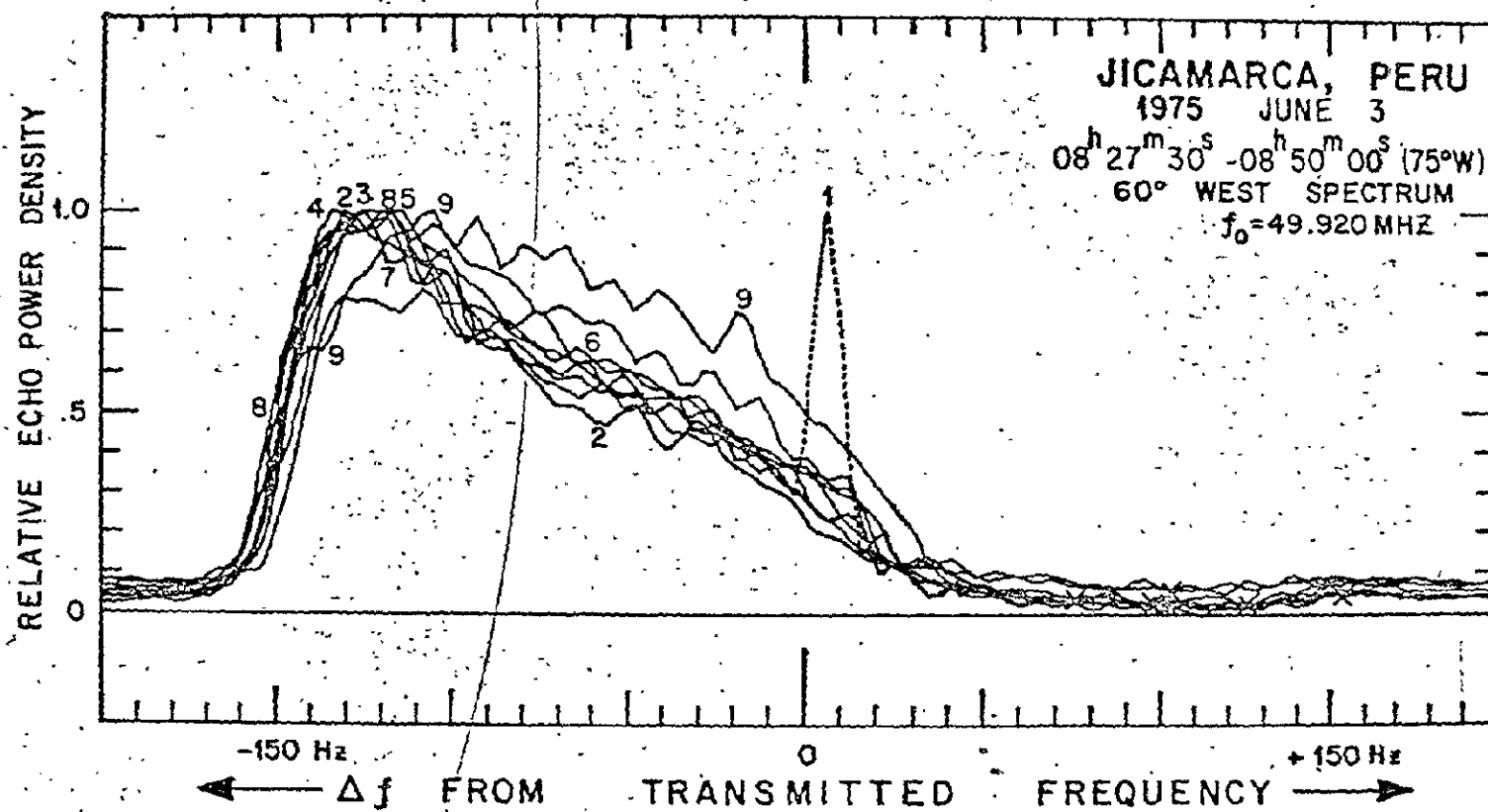
N° 2,767
 ALONT.75

Fig. 34



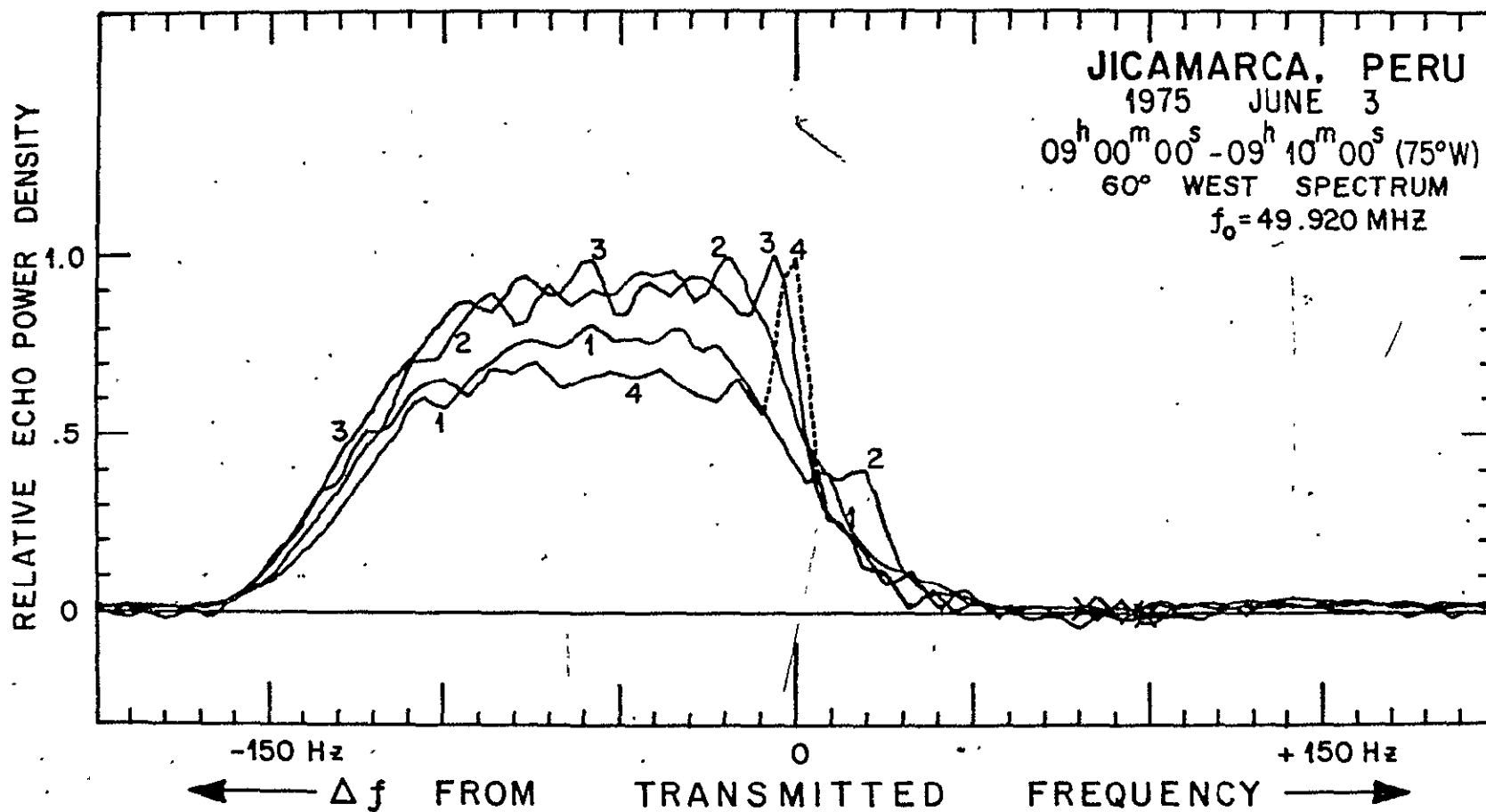
Nº 2,768
ALDHT. 75

Fig. 35



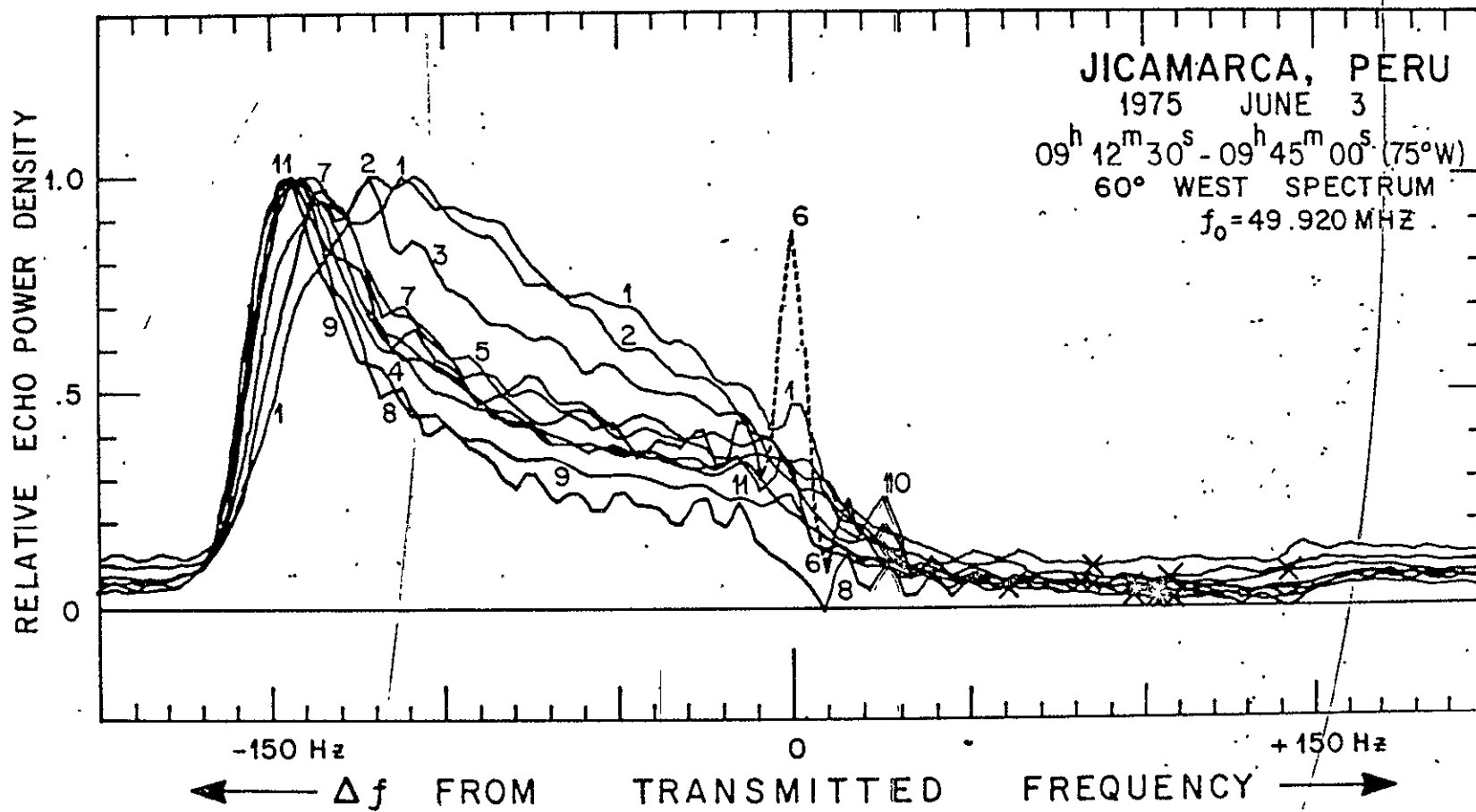
Nº 2,774
ALDHT-75

Fig. 36



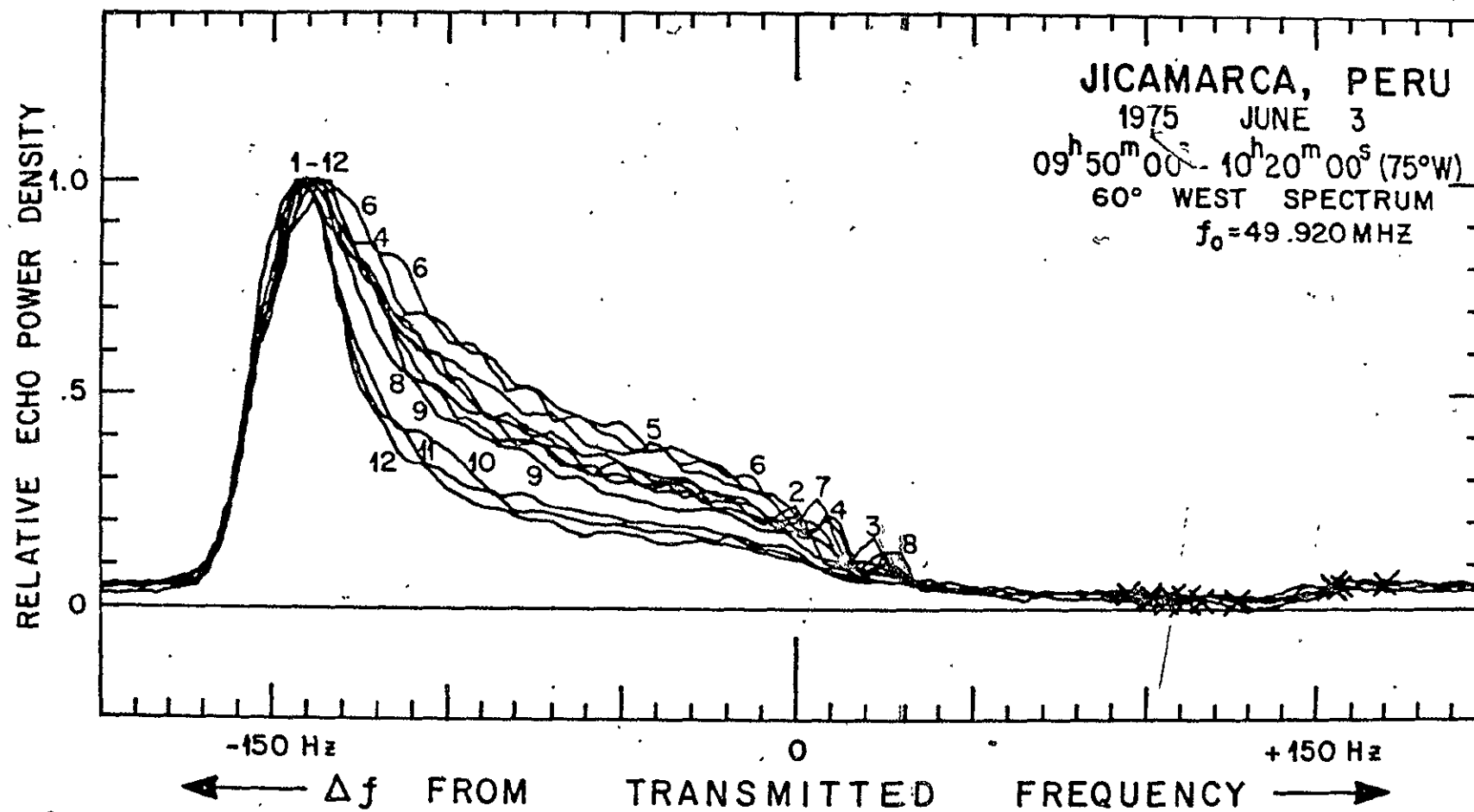
Nº2,775
 ALOHT-75

Fig. 37



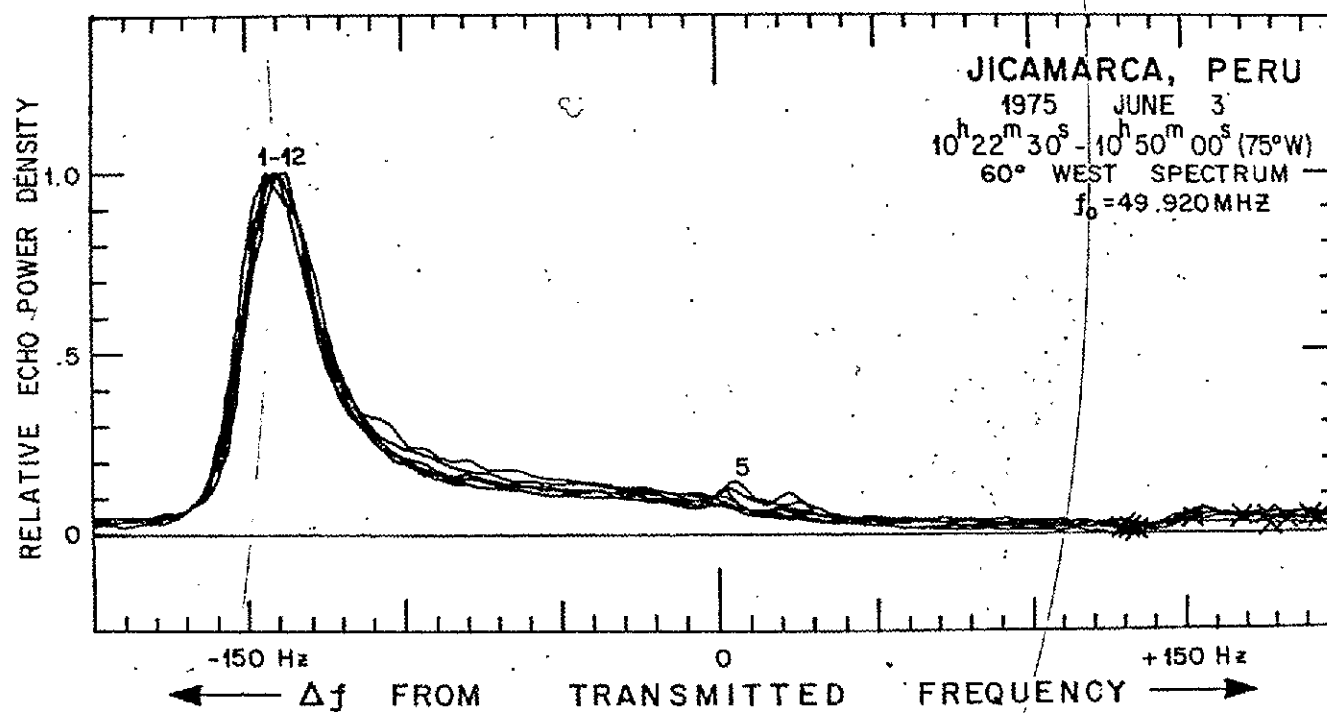
Nº2,776
ALOH-75

Fig. 38



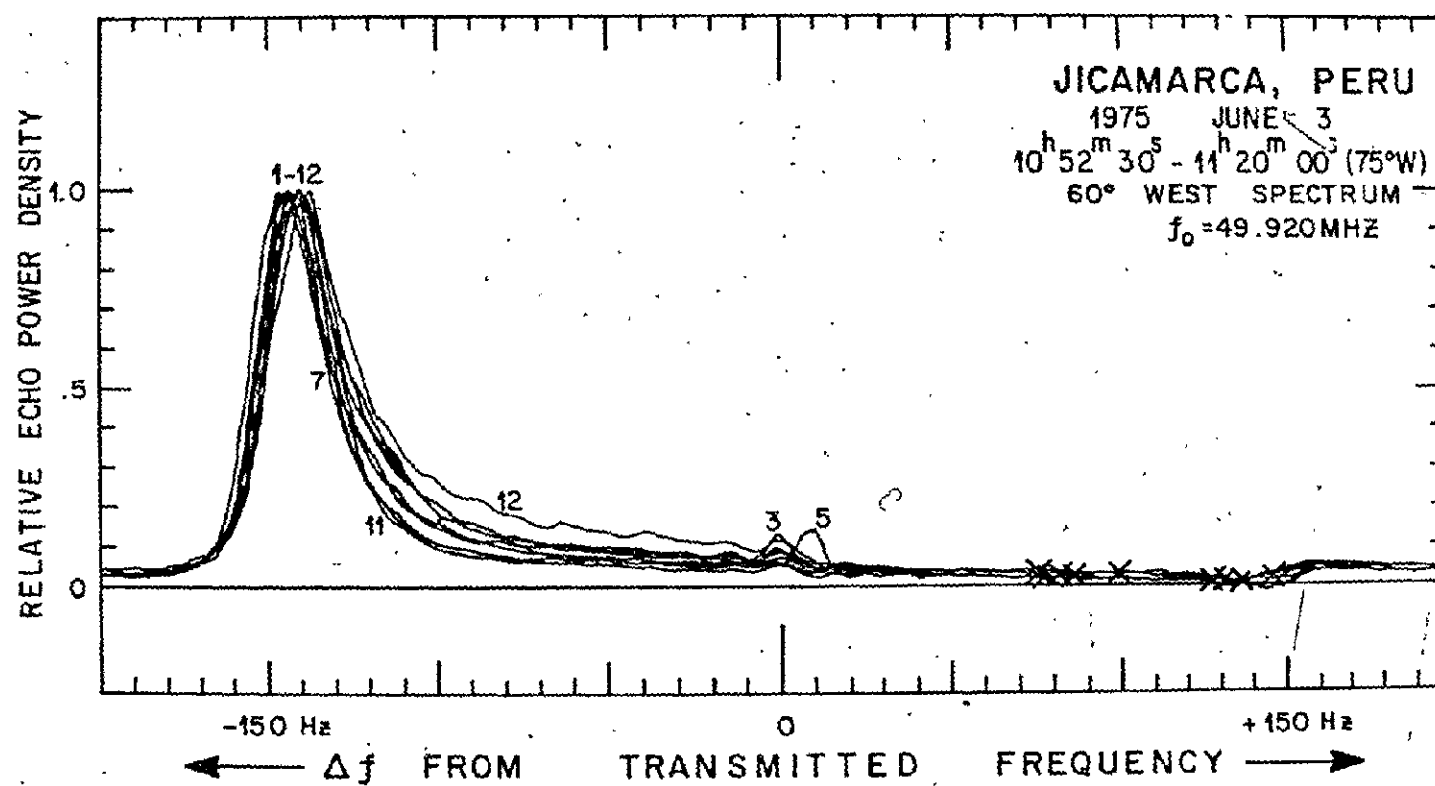
Nº2,777
ALOH-75

Fig. 39



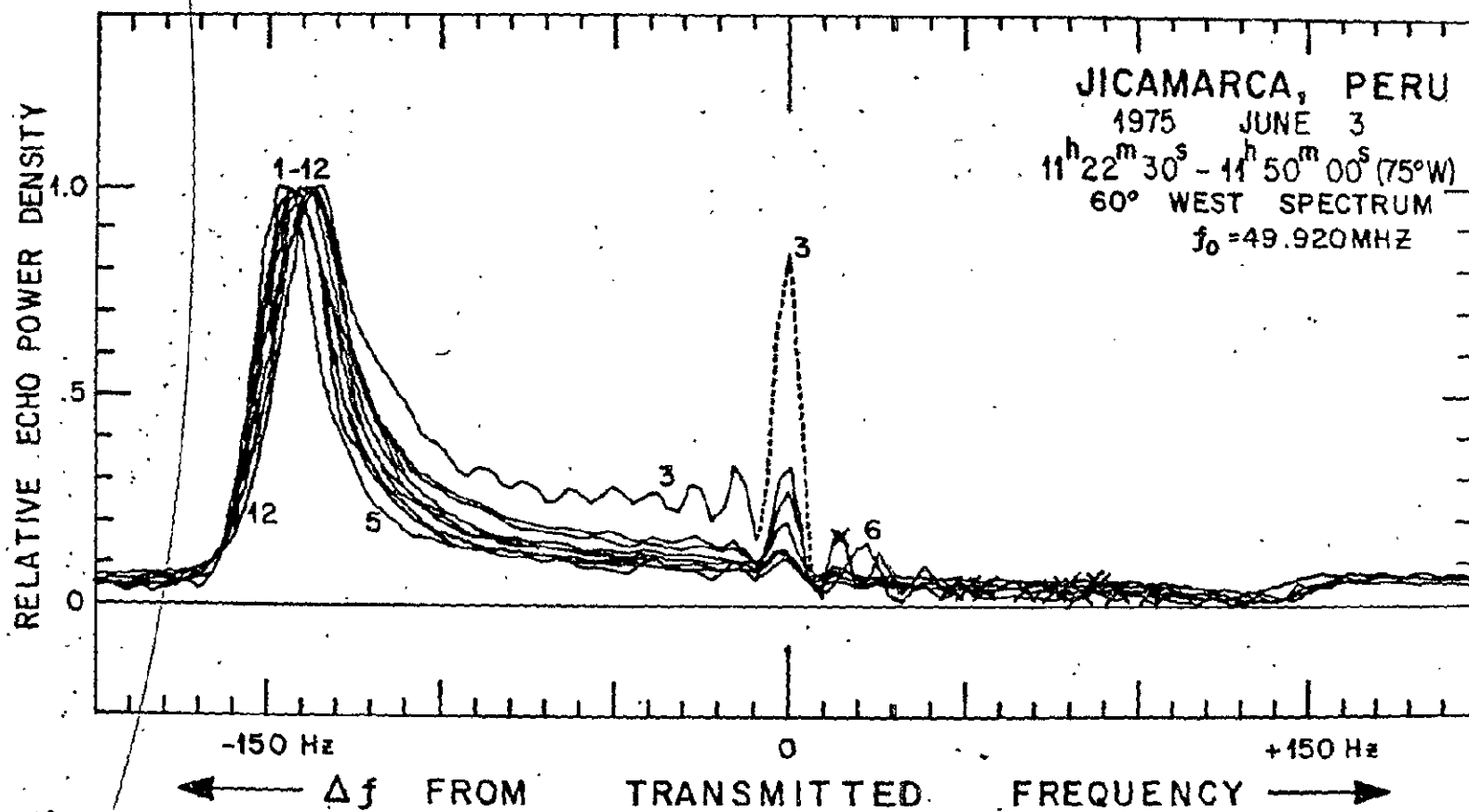
Nº2,778
 ALCHT-75

Fig. 40



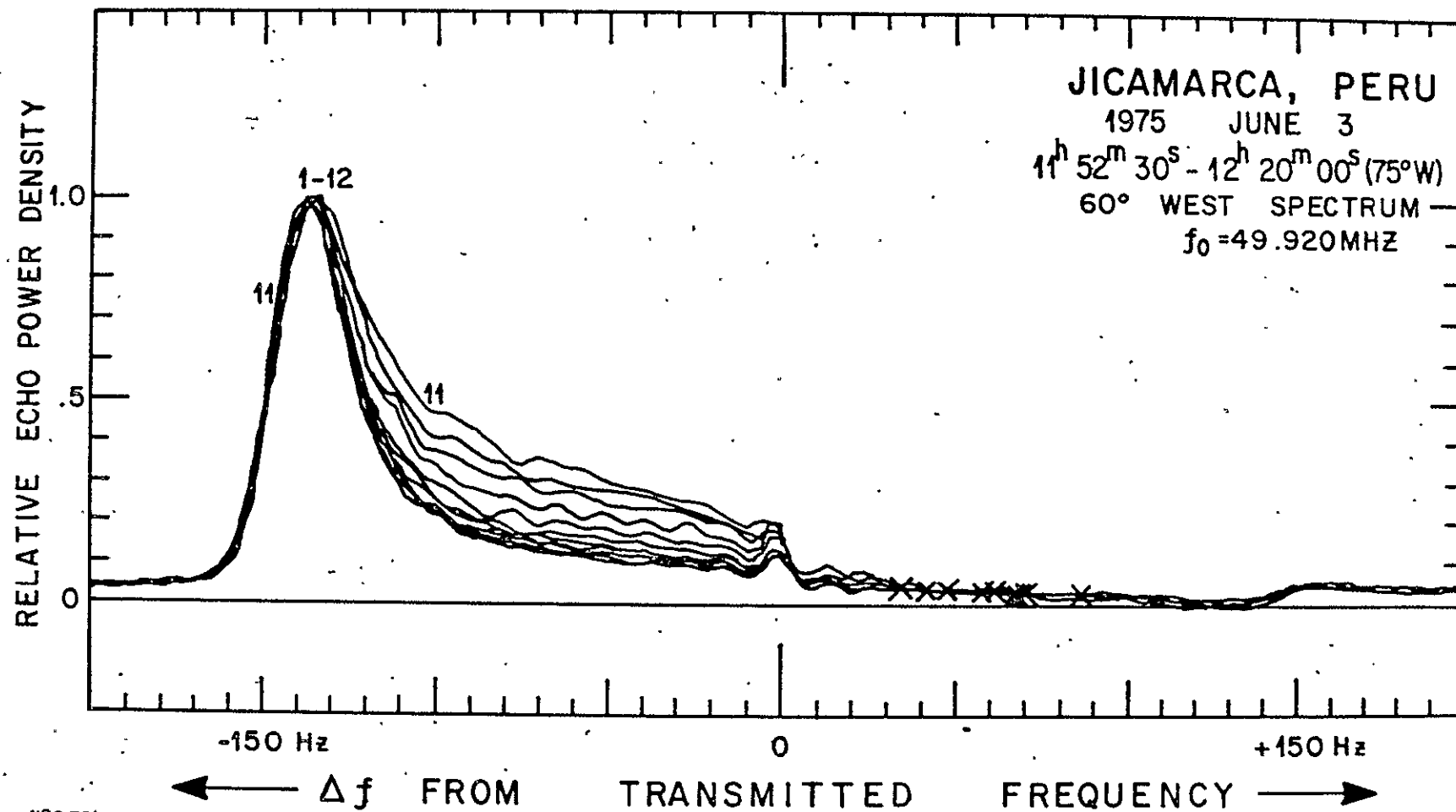
Nº2,779
ALOMT-75

Fig. 41



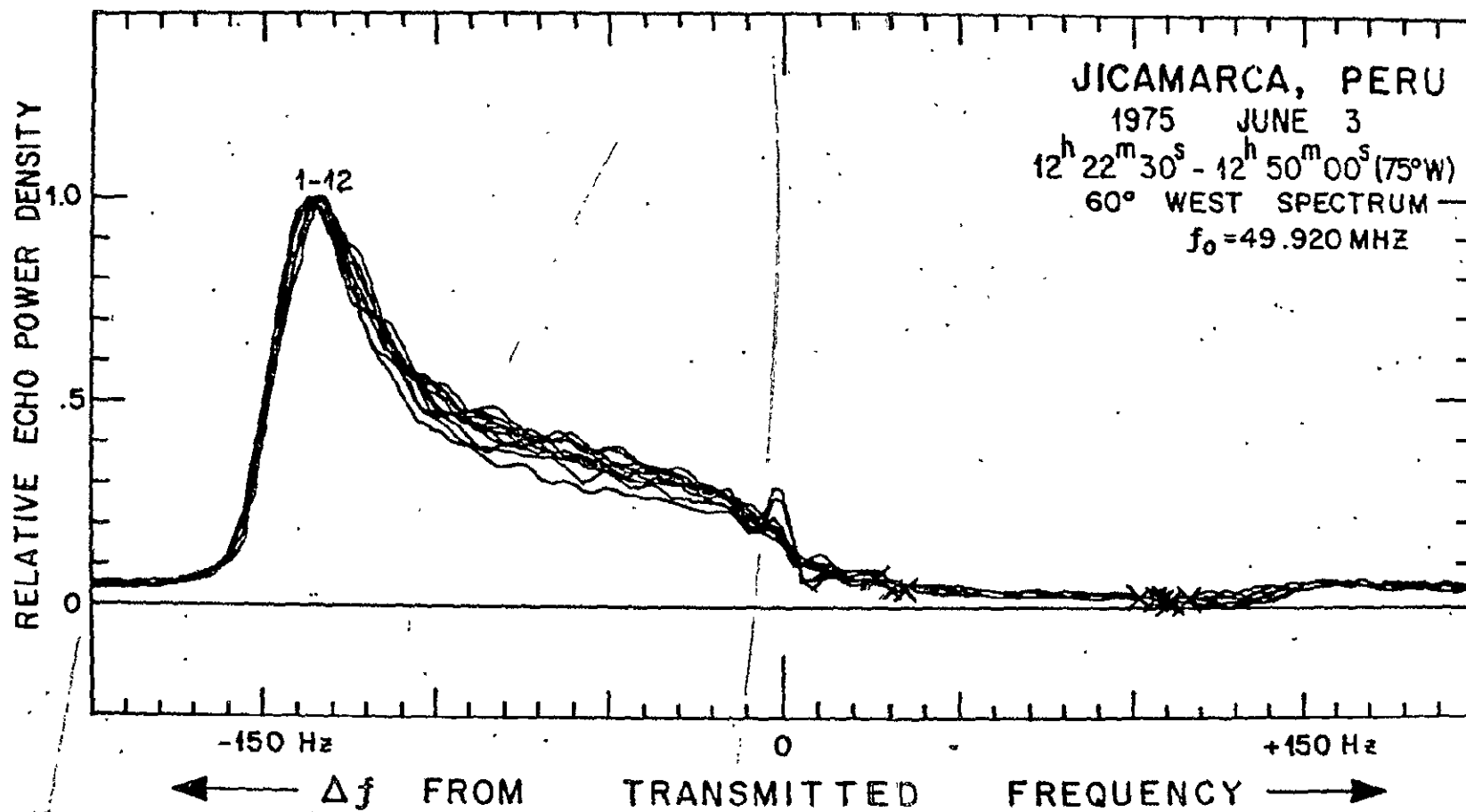
Nº2,780
ALOH7-75

Fig. 42



N°2,781
 ALOHT-75

Fig. 43



Nº 2,782
ALONT, 75

Fig. 44

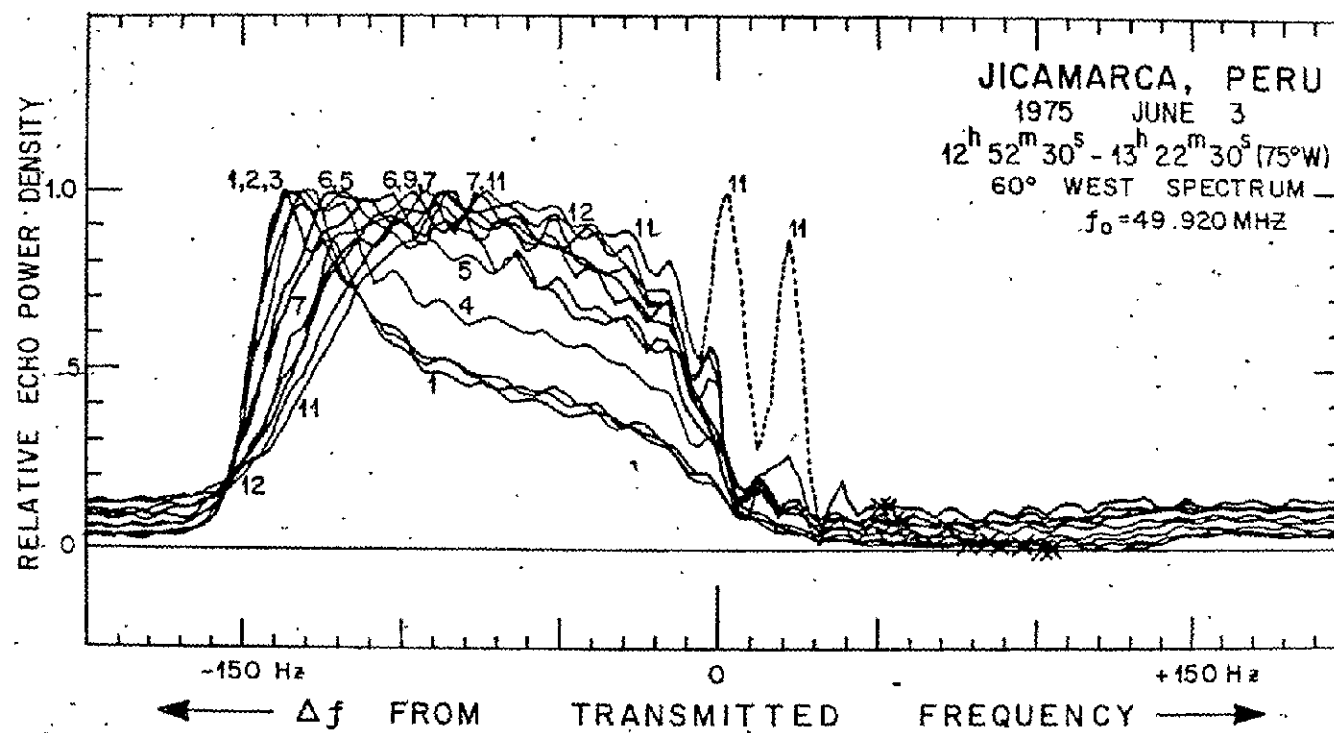
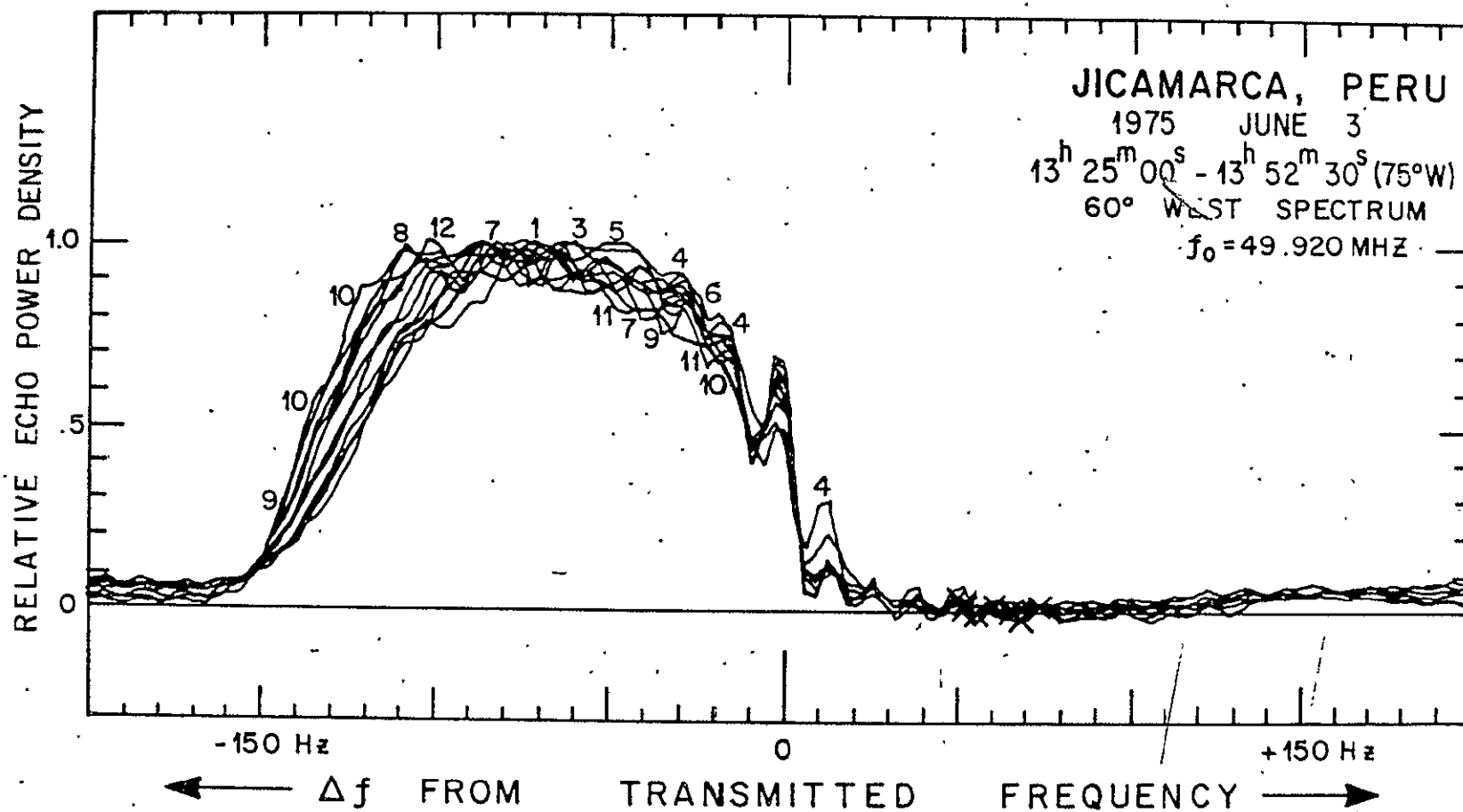
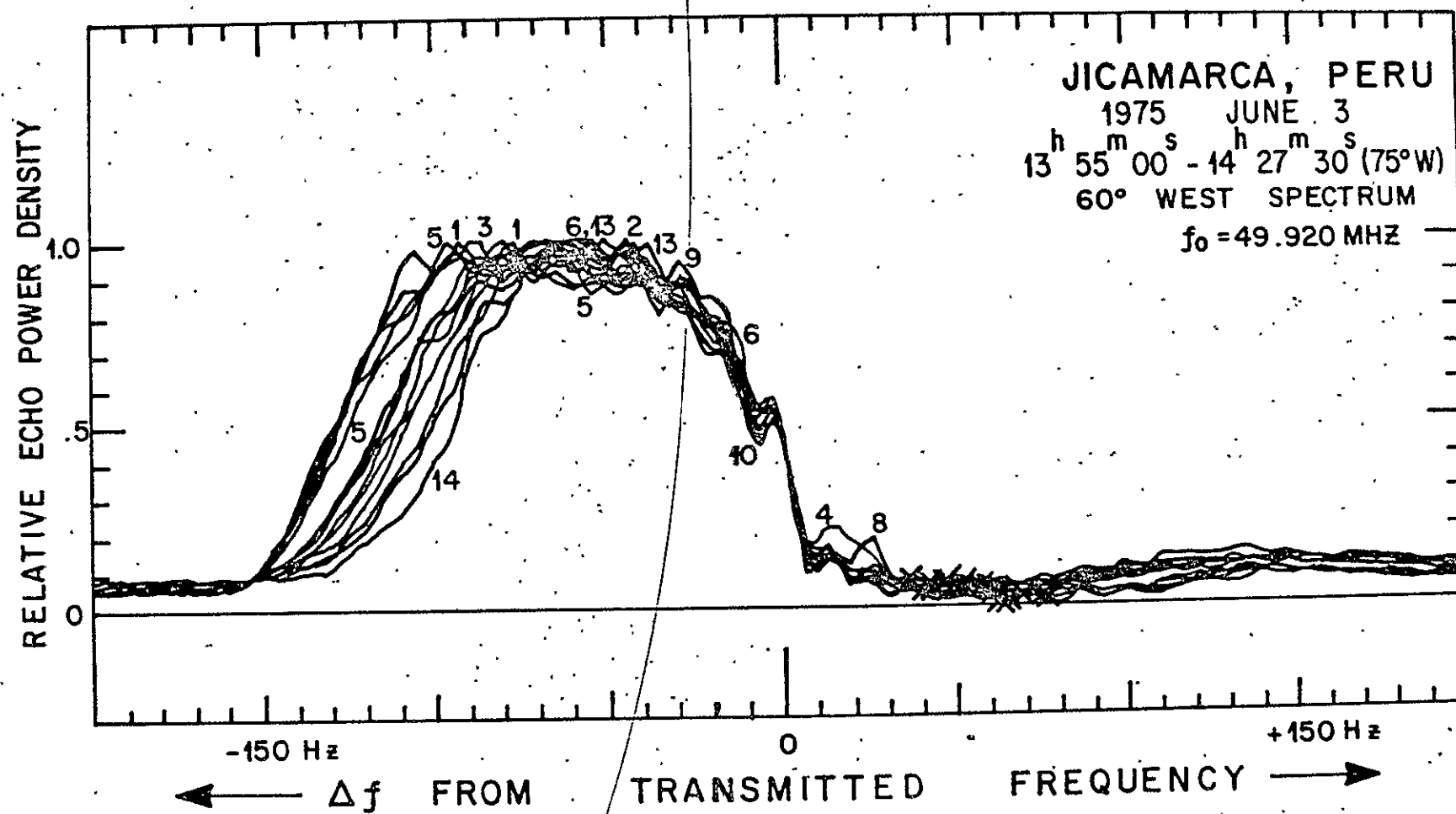


Fig. 45



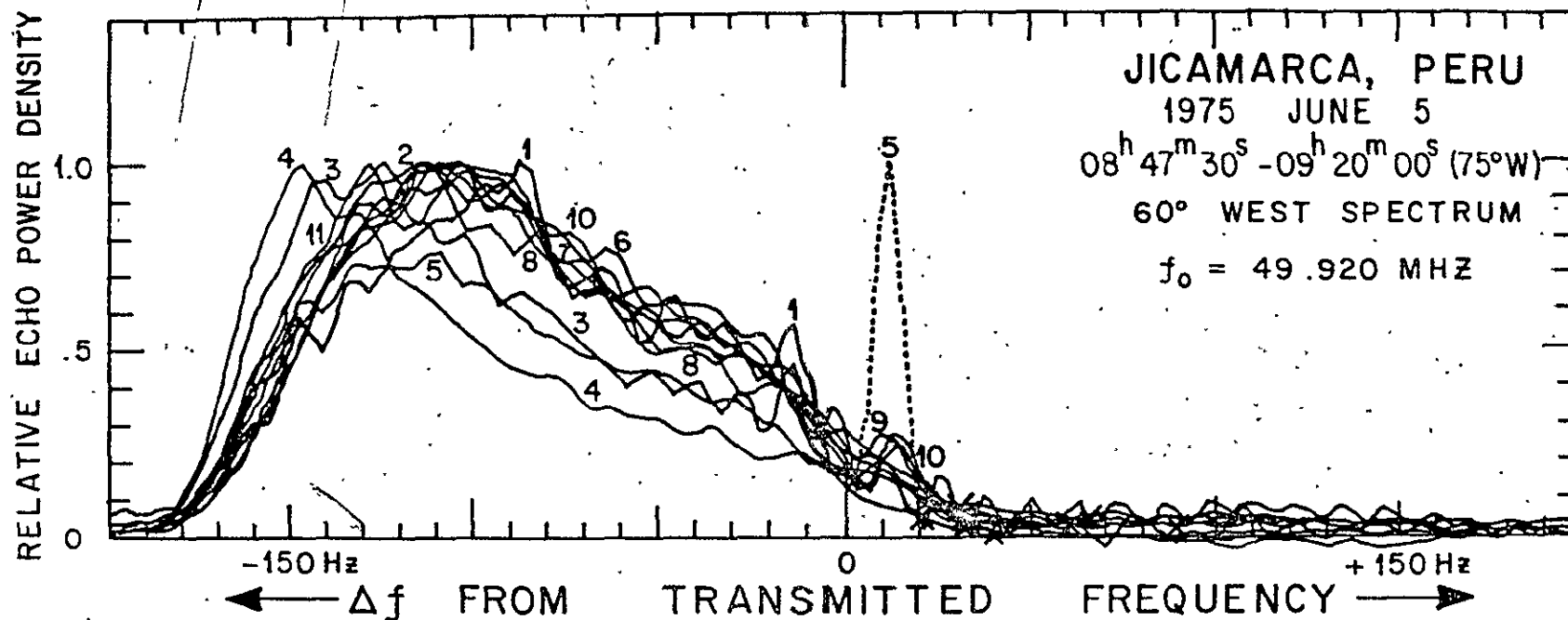
Nº 2,784
ALONT-75

Fig. 46



Nº 2,785
ALOMT-75

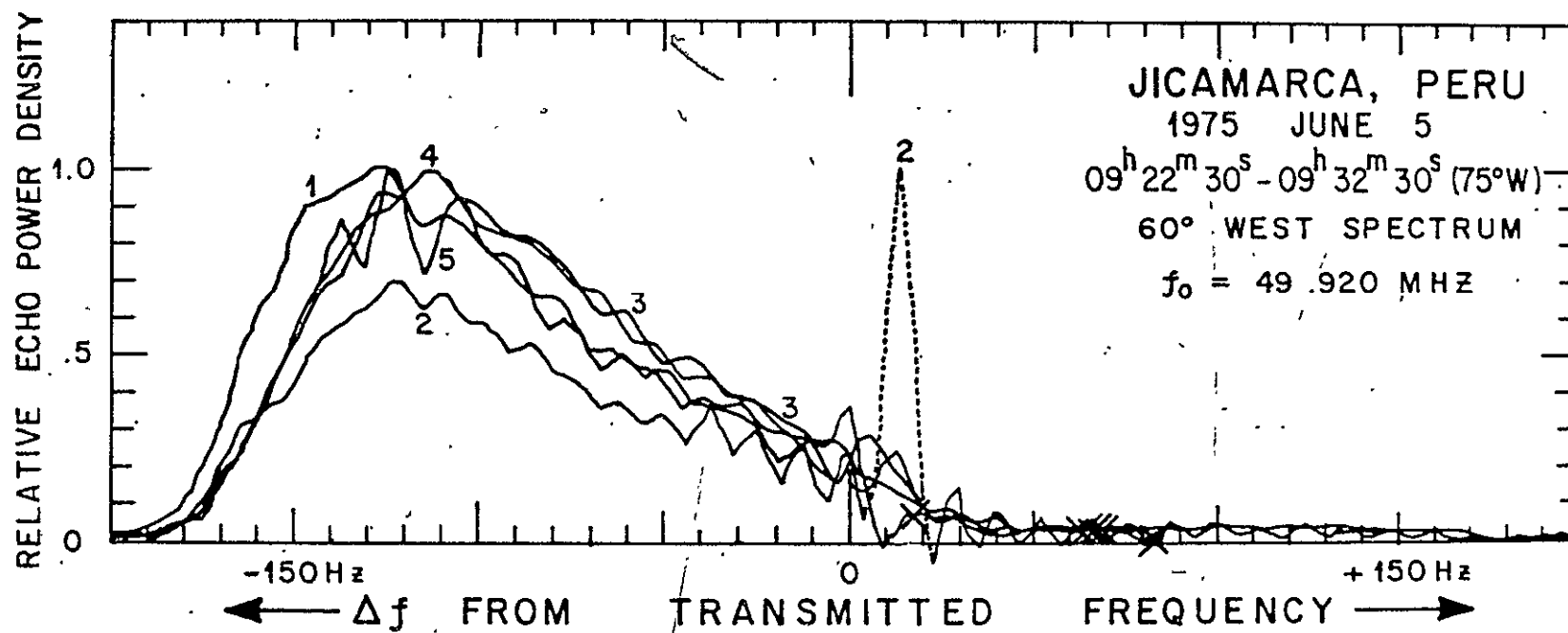
Fig. 47



Nº 2,757
ALOMT. 75

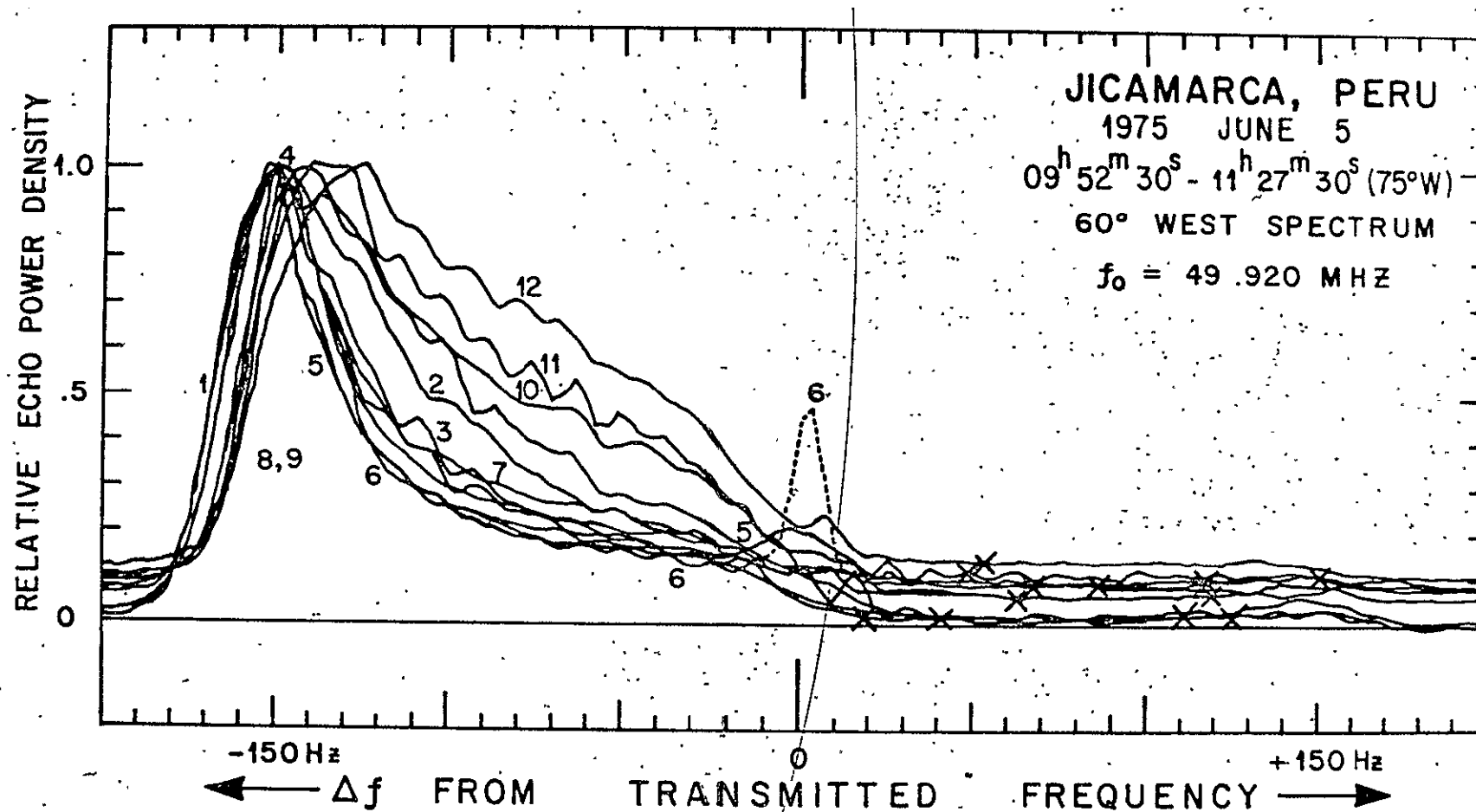
Fig. 48

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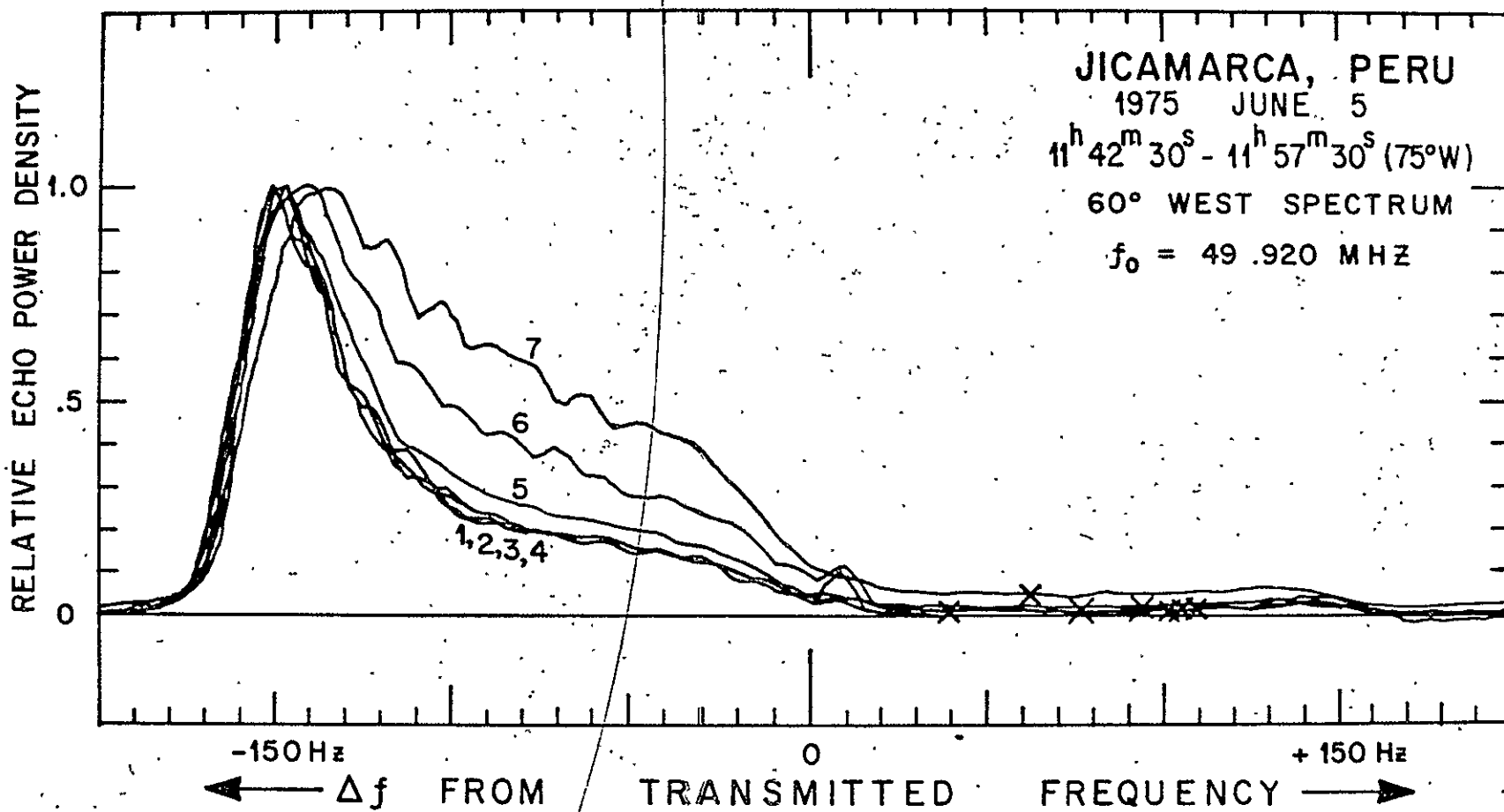
Nº 2,758
ALOH75

Fig. 49



Nº 2,759
ALOH 7.75

Fig. 50



Nº 2760
ALOHT. 75

Fig. 51

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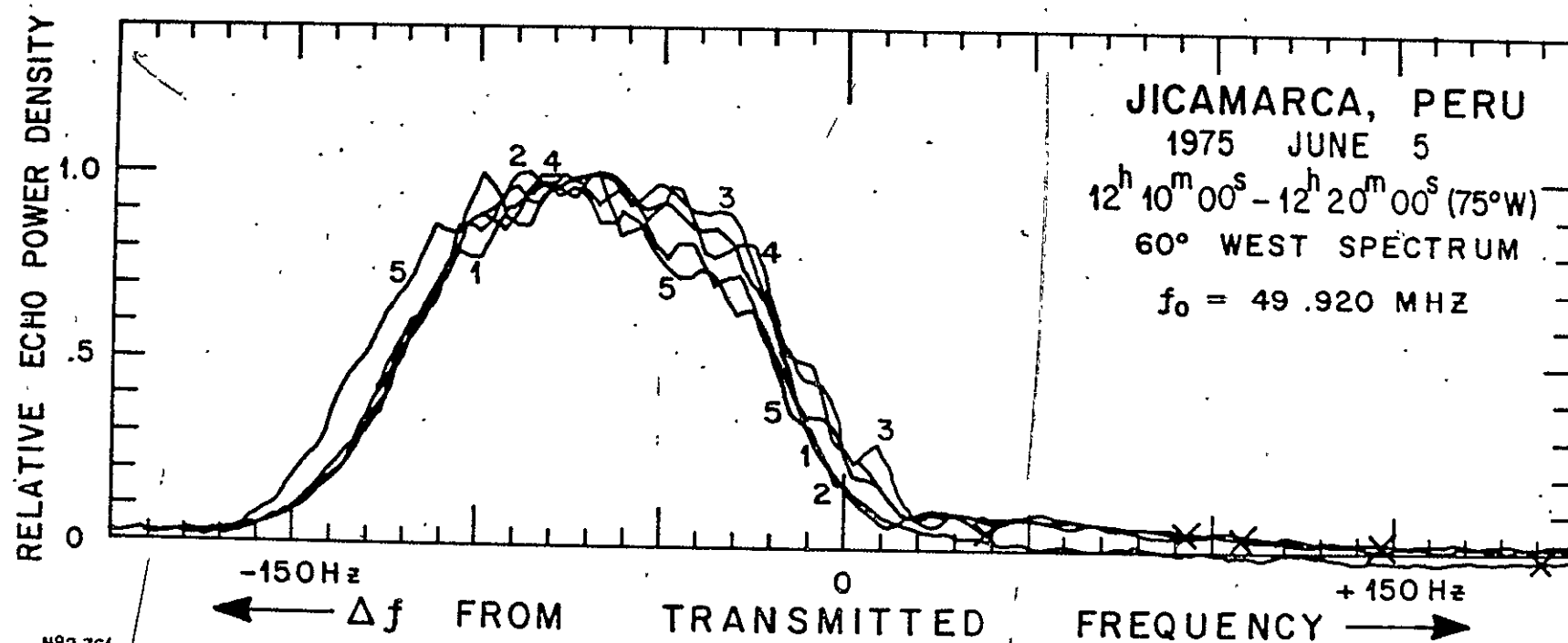
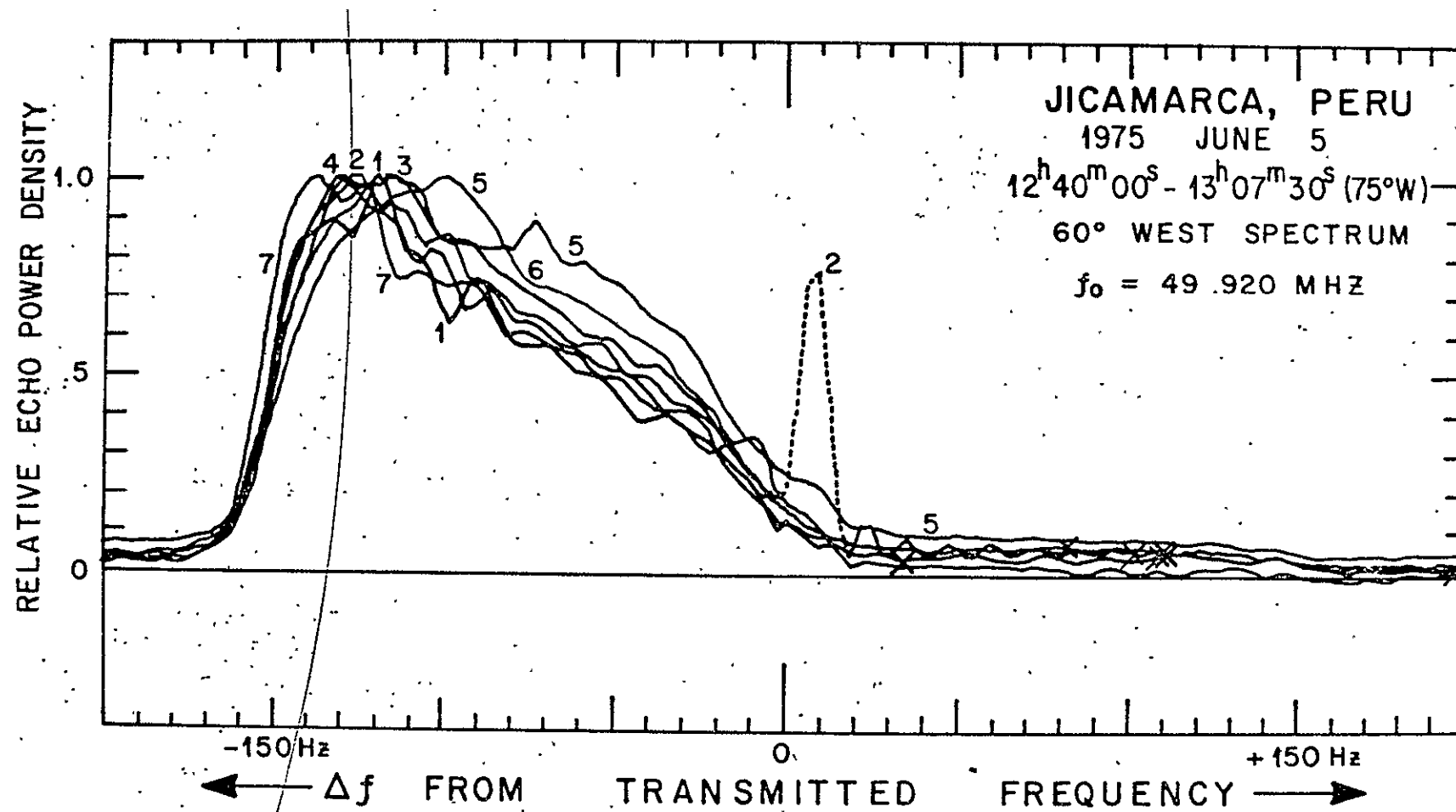
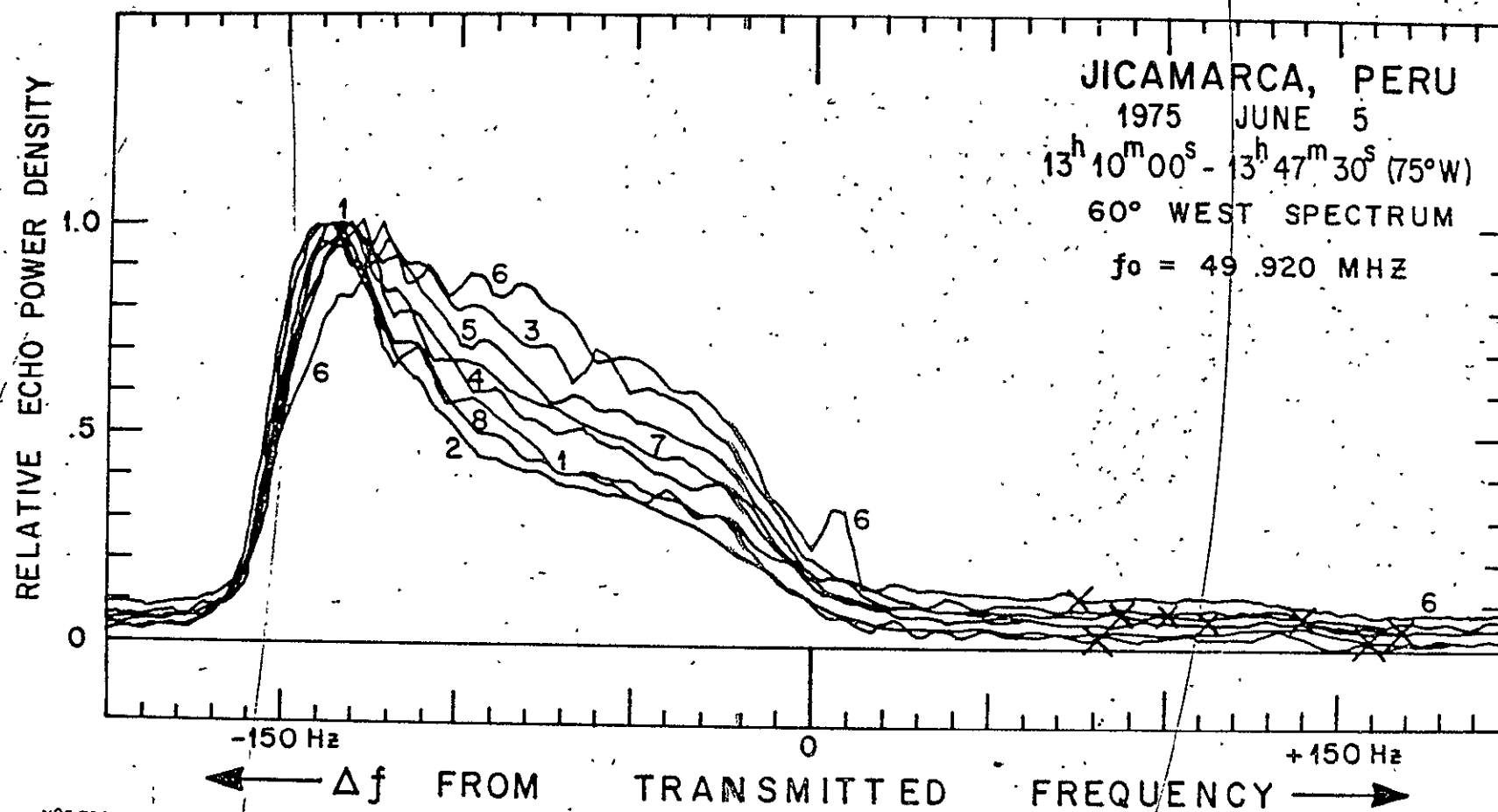


Fig. 52



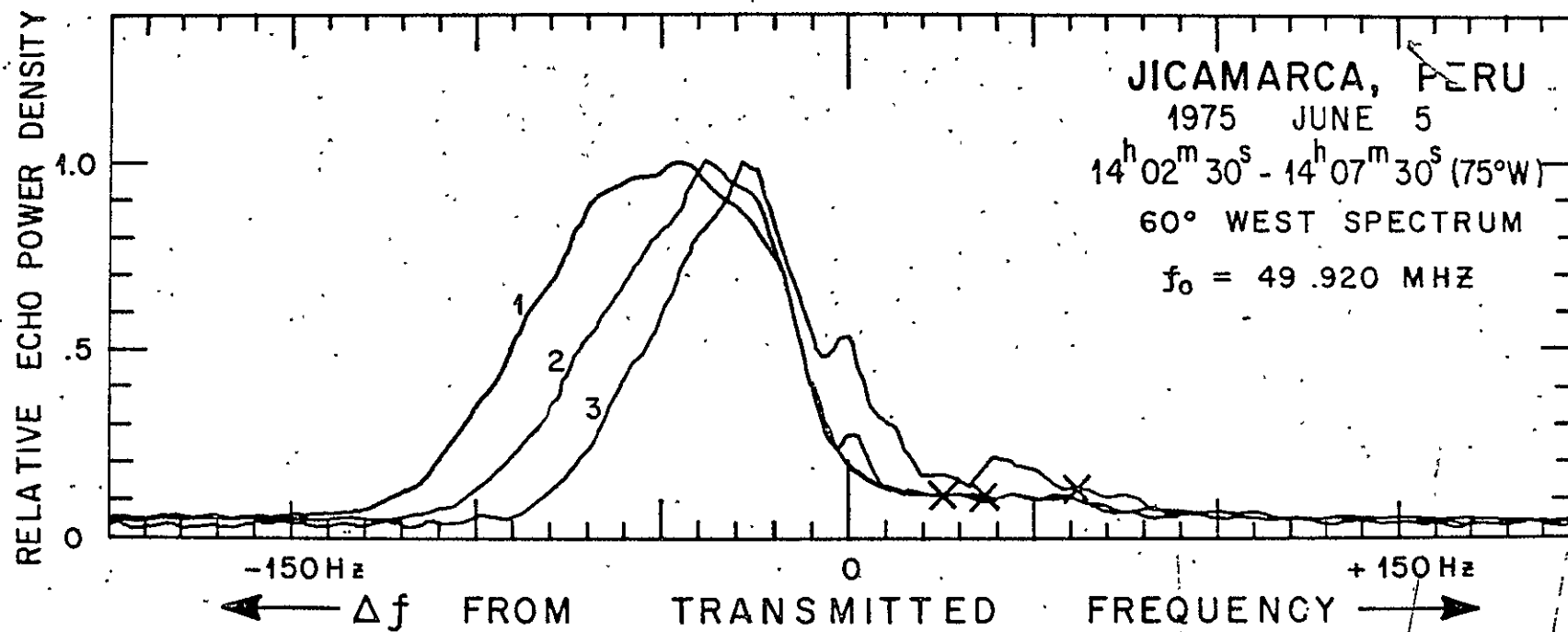
Nº 2,763
ALOHT-75

Fig. 53 /



Nº2,764
ALOHT-75

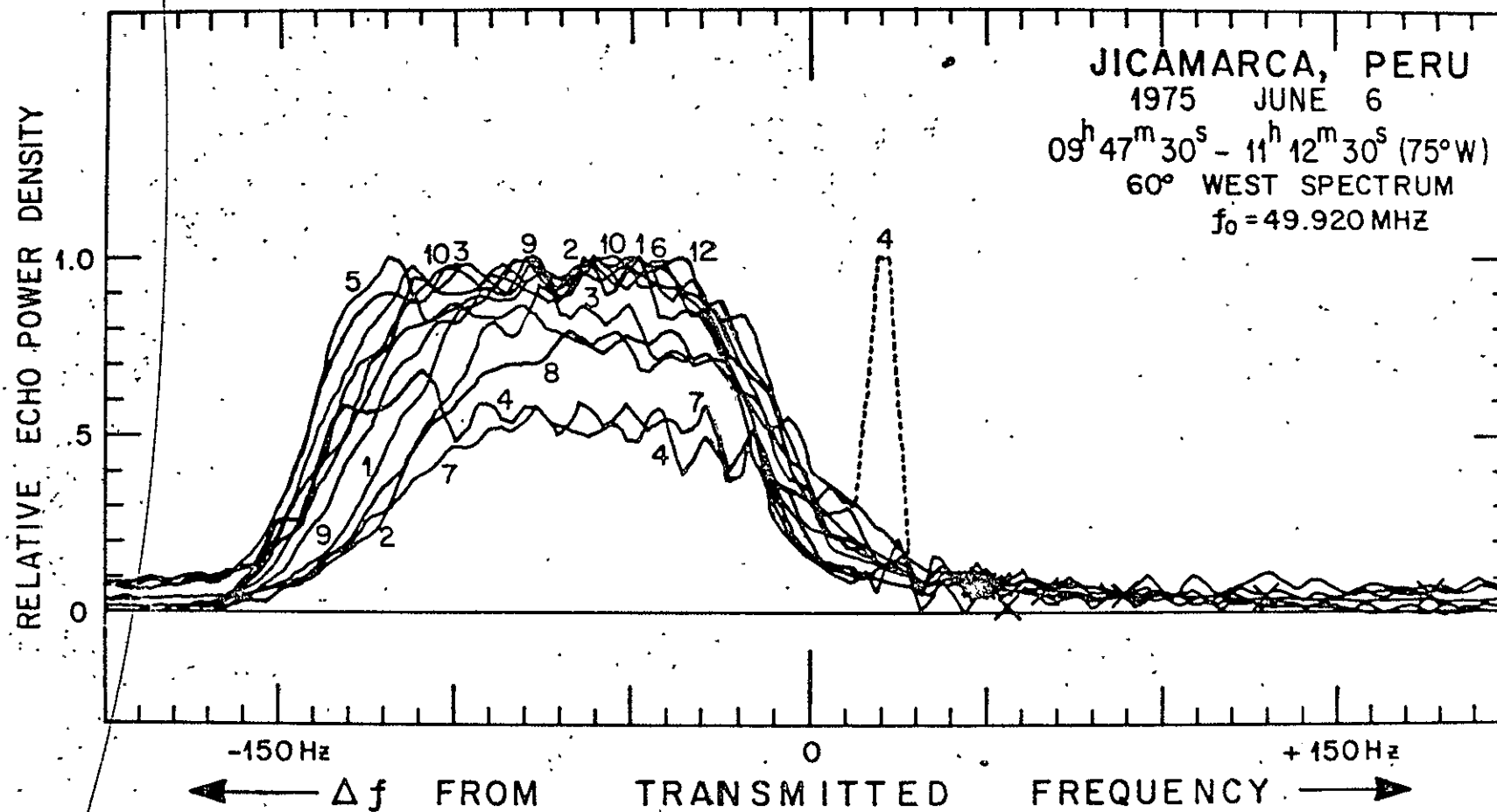
Fig. 54



N°2,765
ALOH, 75

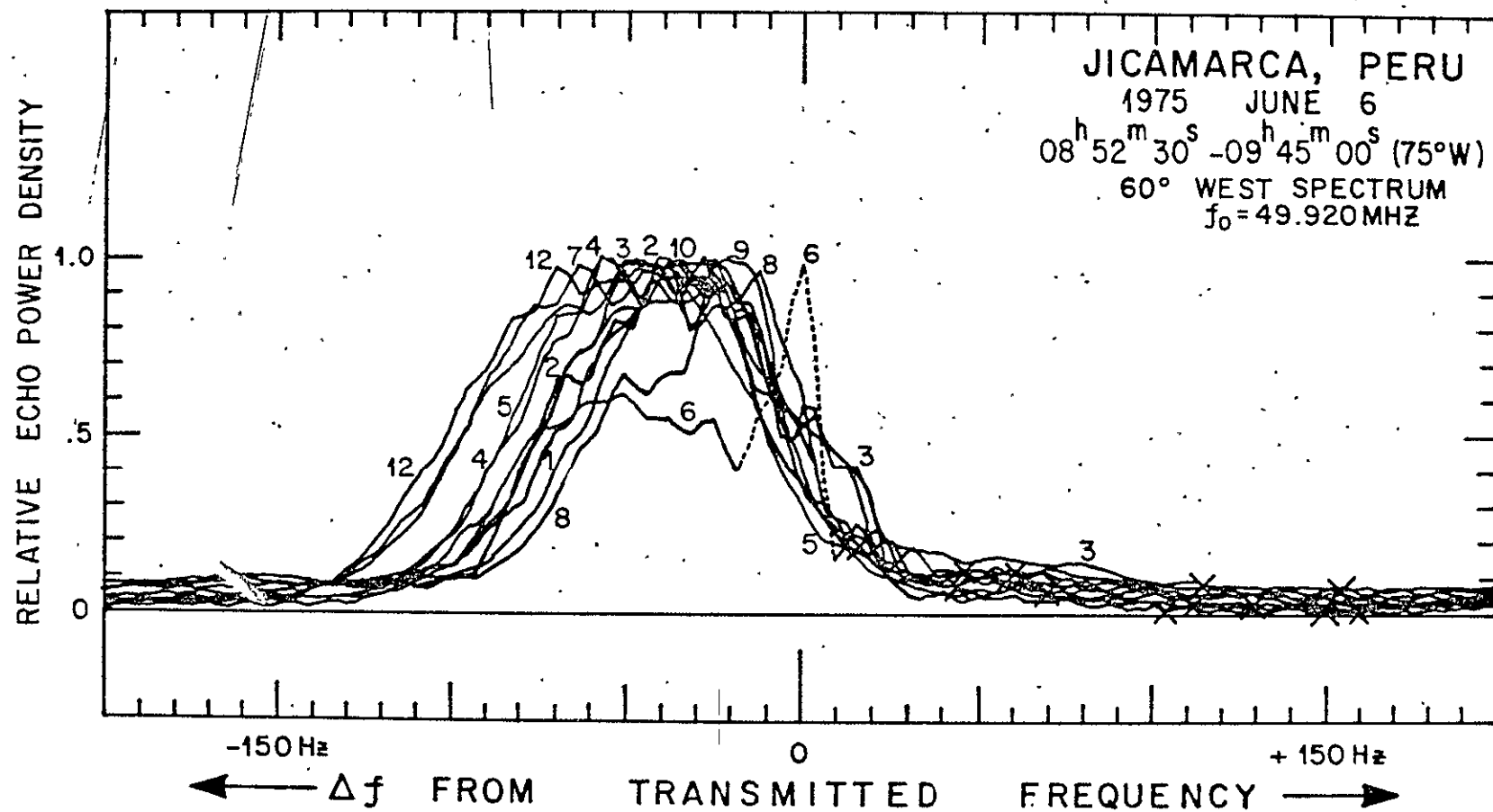
Fig. 55

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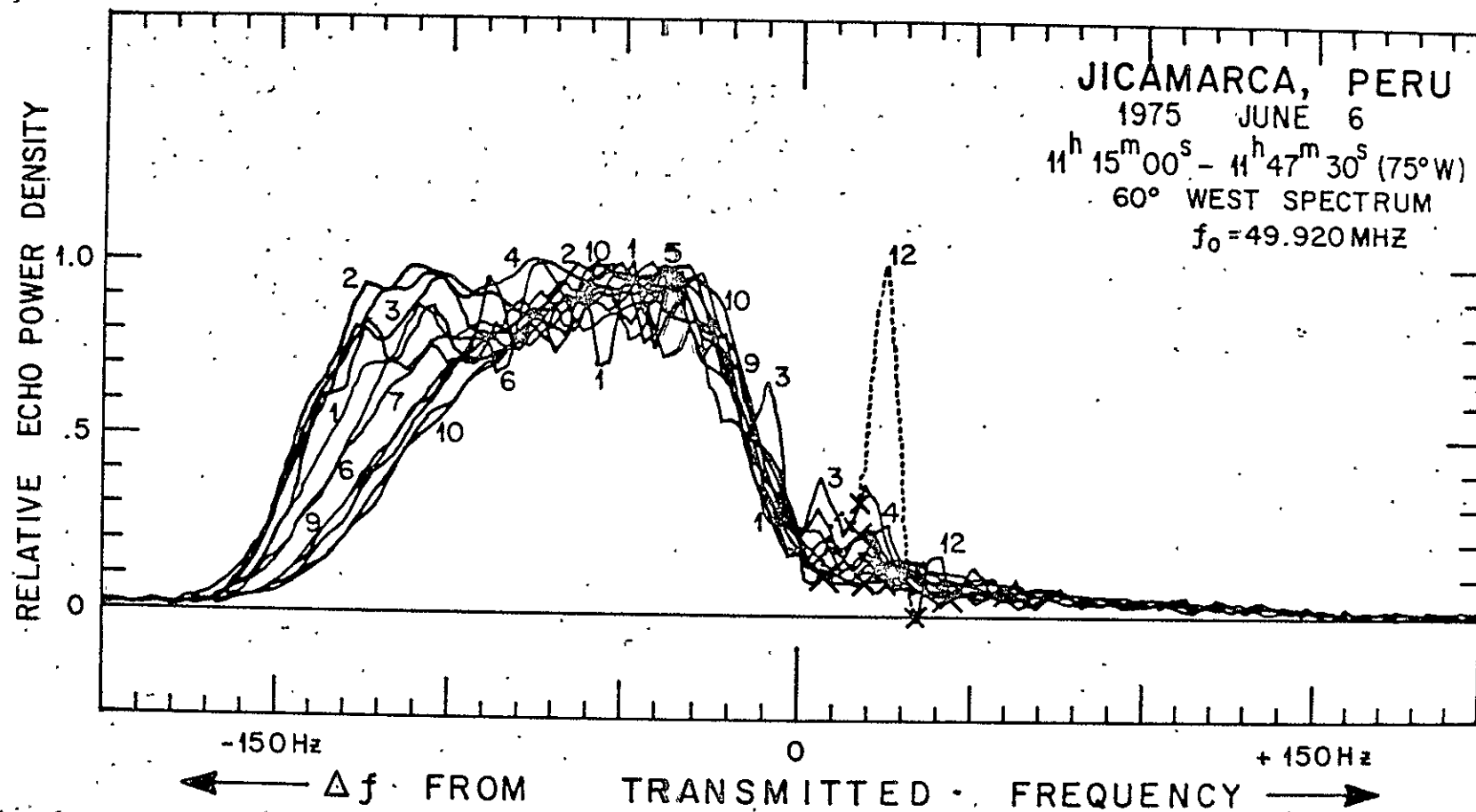
Nº 2.770
ALOHU-75

Fig. 56



N° 2,769
ALOHT-75

Fig. 57



Nº 2,771
ALOHT-75

Fig. 58

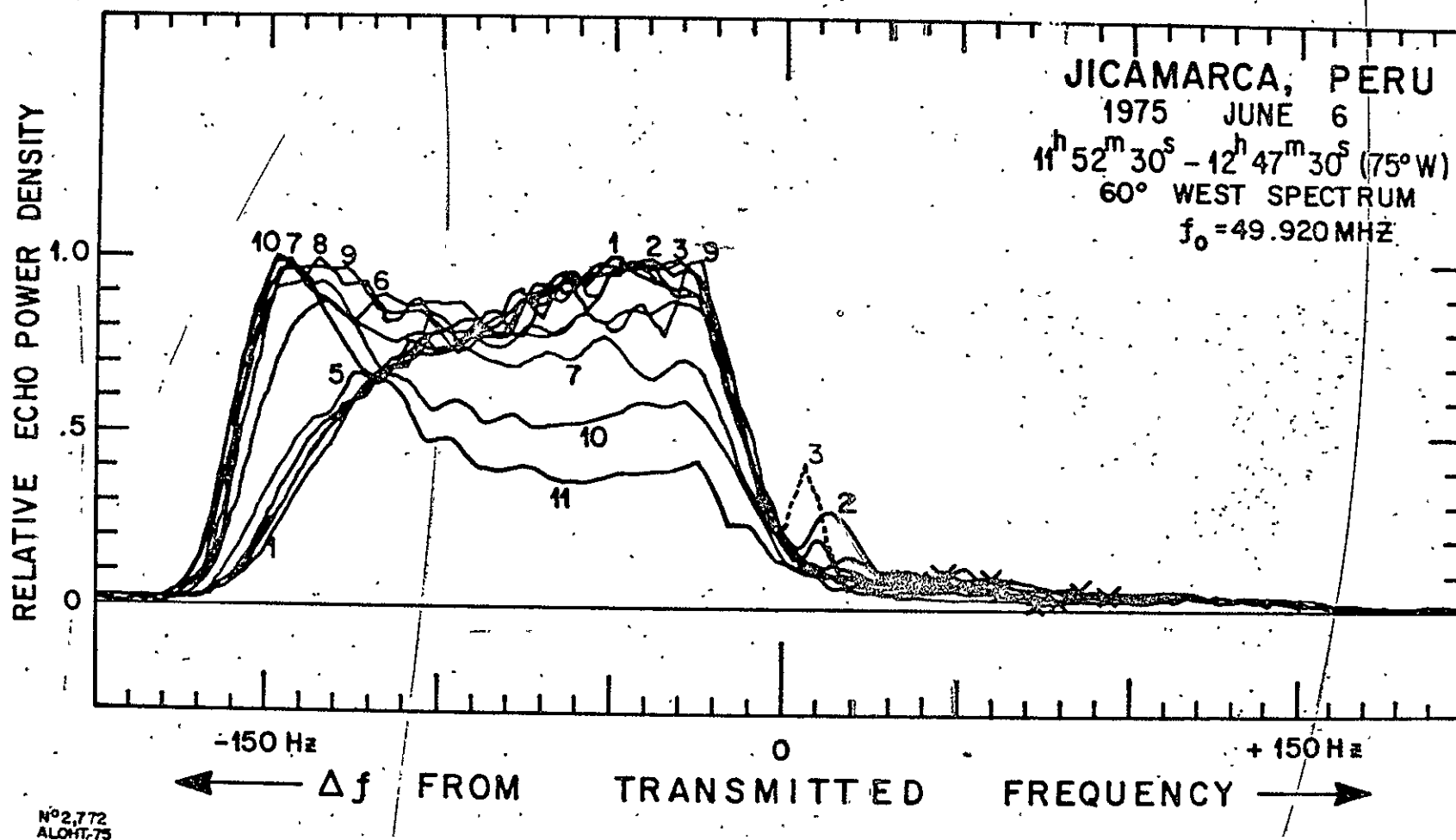
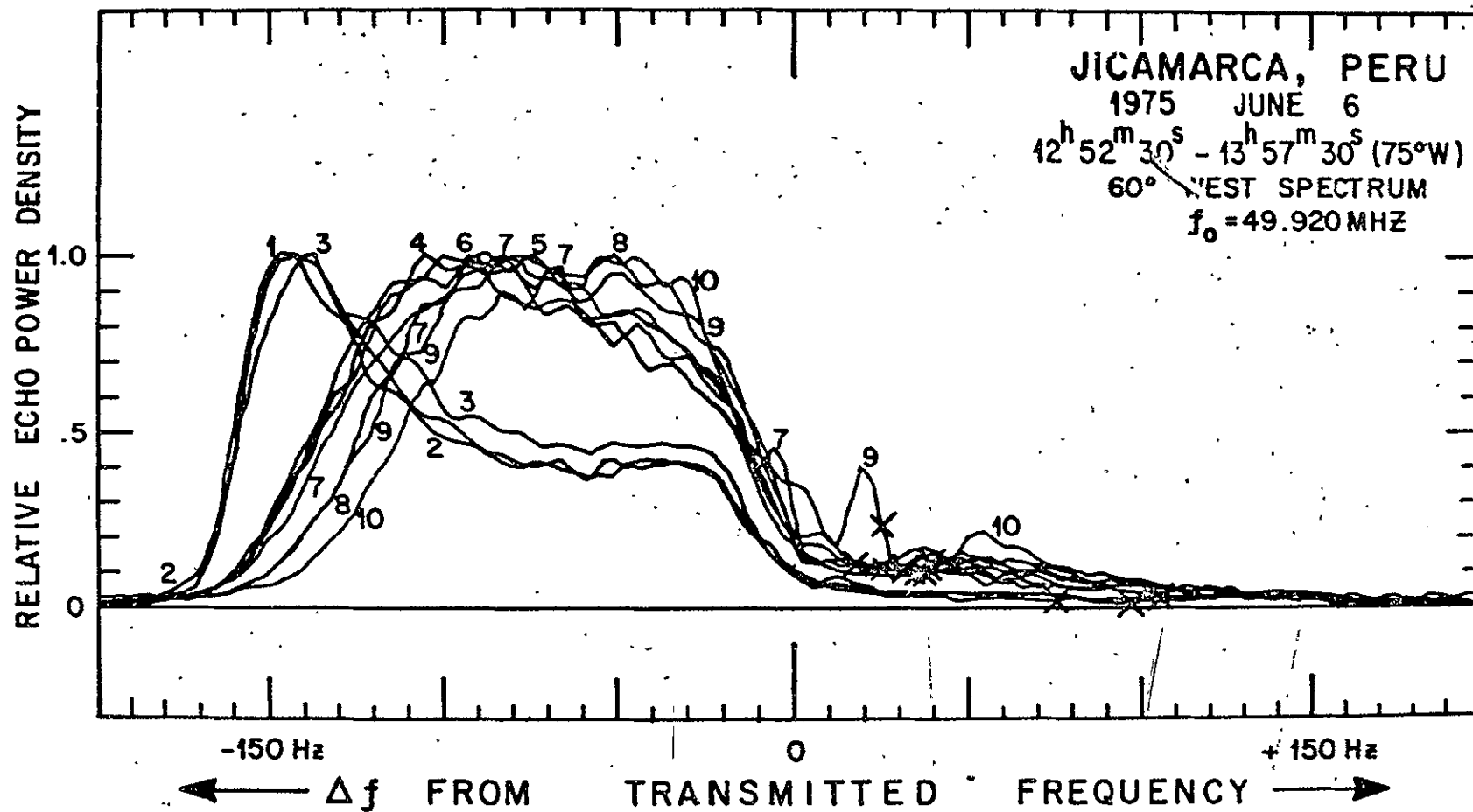
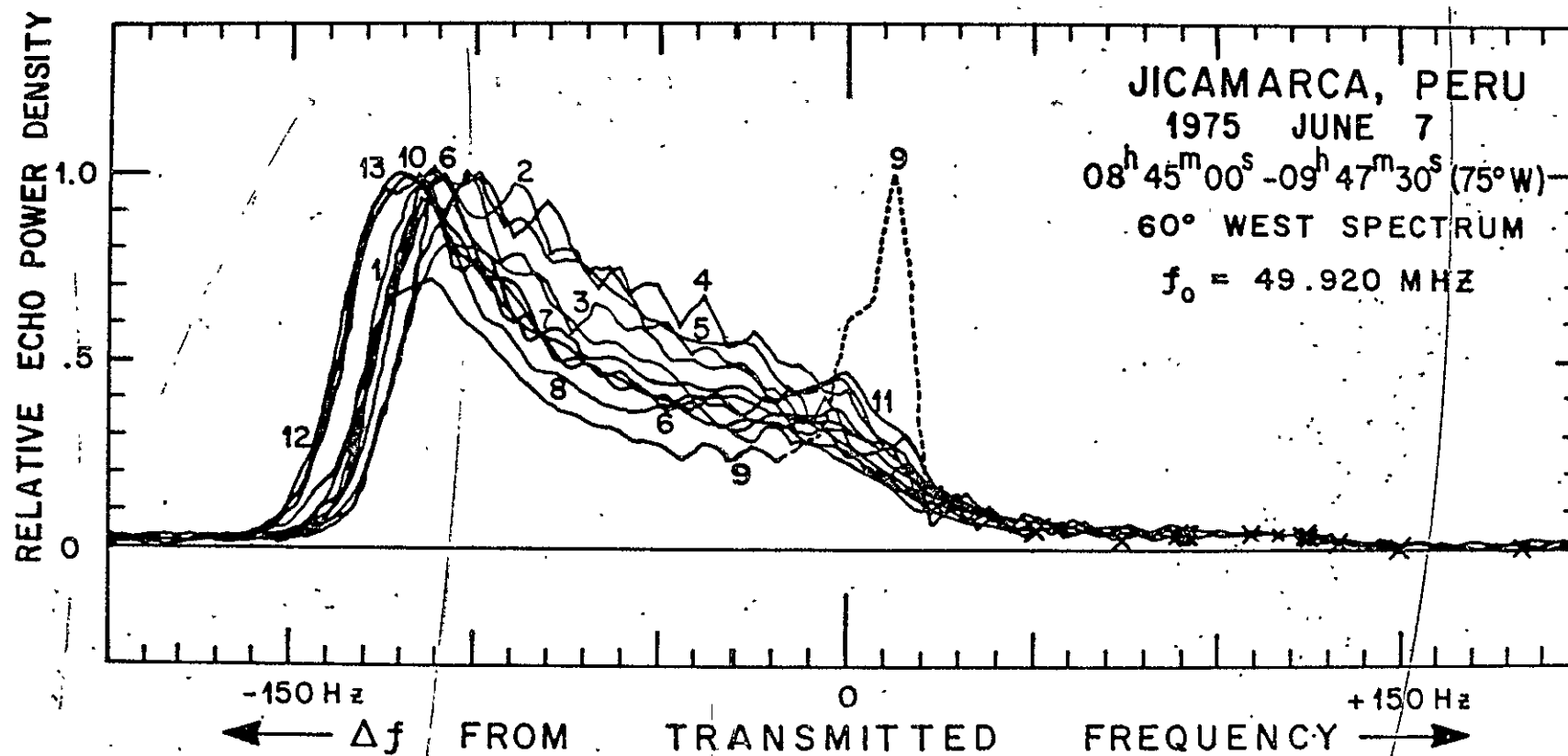


Fig. 59



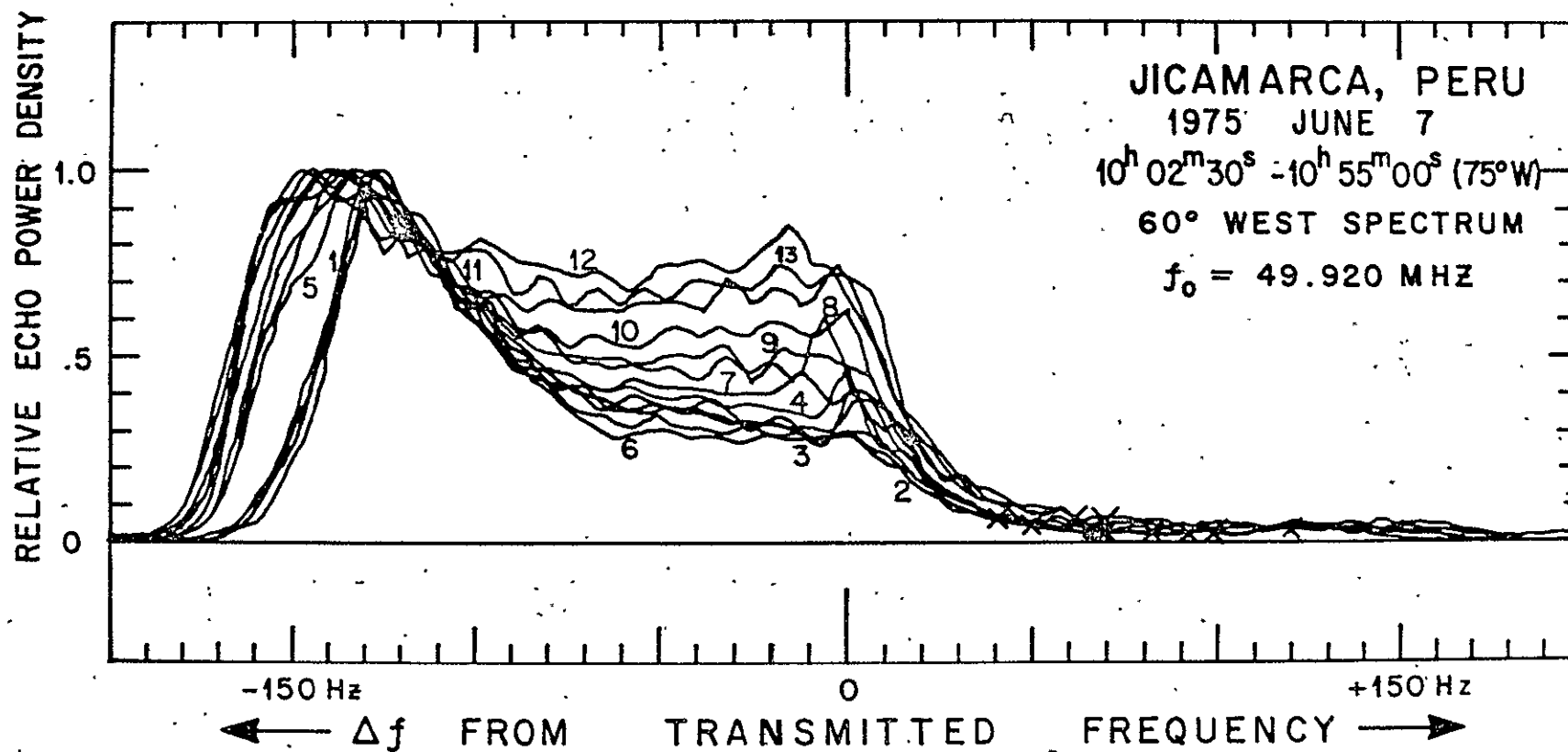
Nº2,773
ALCHIT-75

Fig. 60.



Nº2,748
ALOHT-75

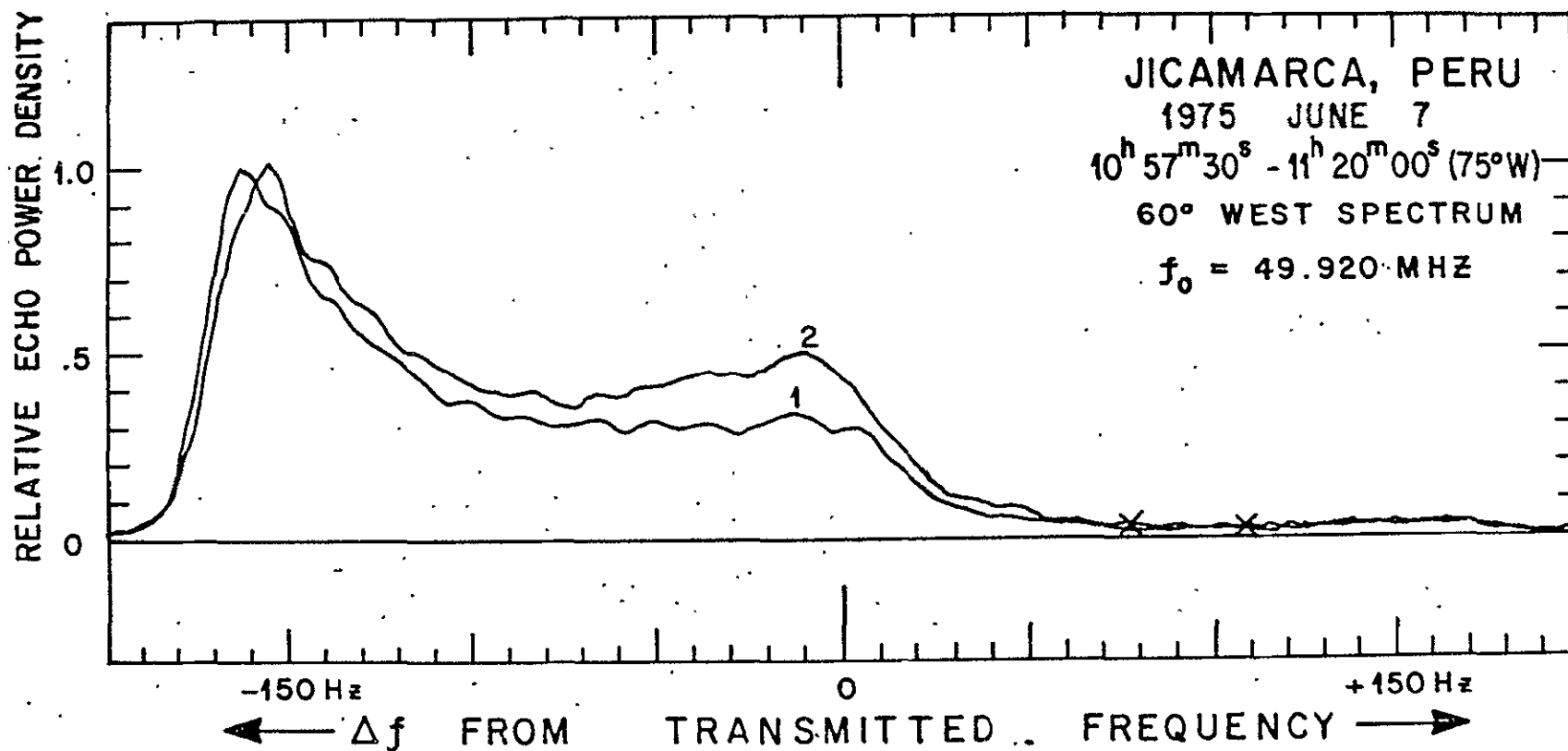
Fig. 61



Nº 2,749
ALOH-75

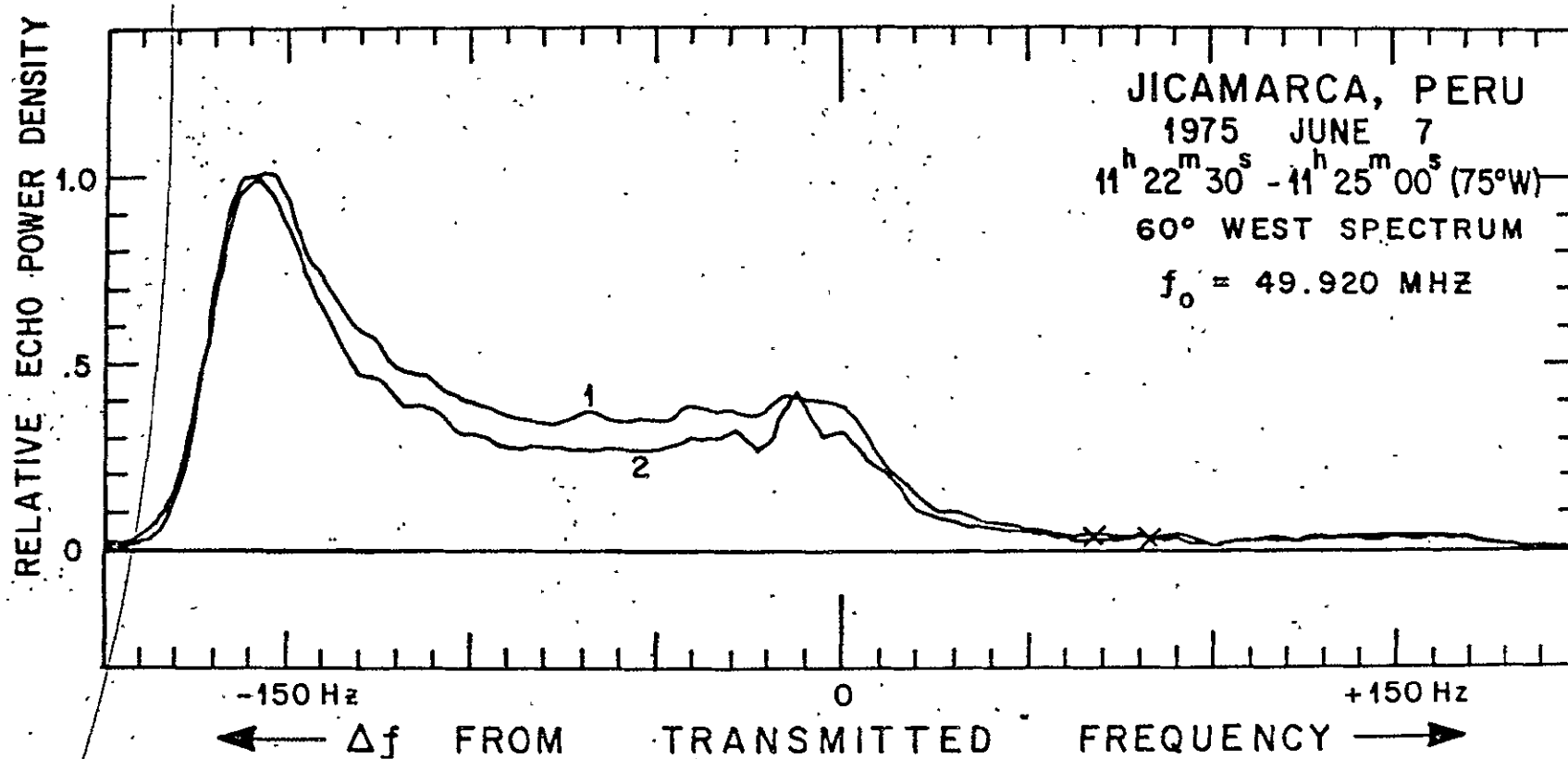
Fig. 62

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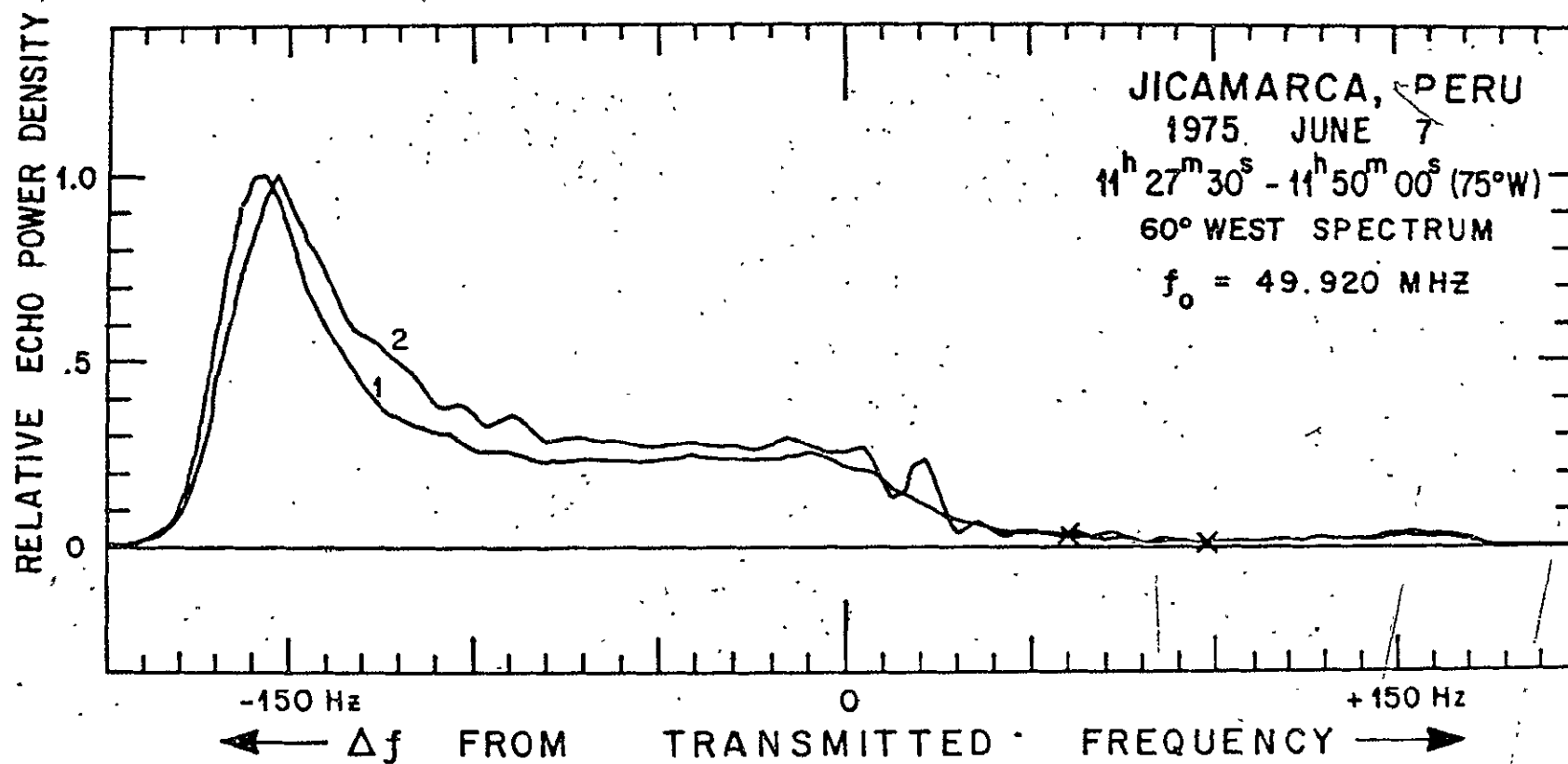
Nº 2,750
ALOHT-75

Fig. 63



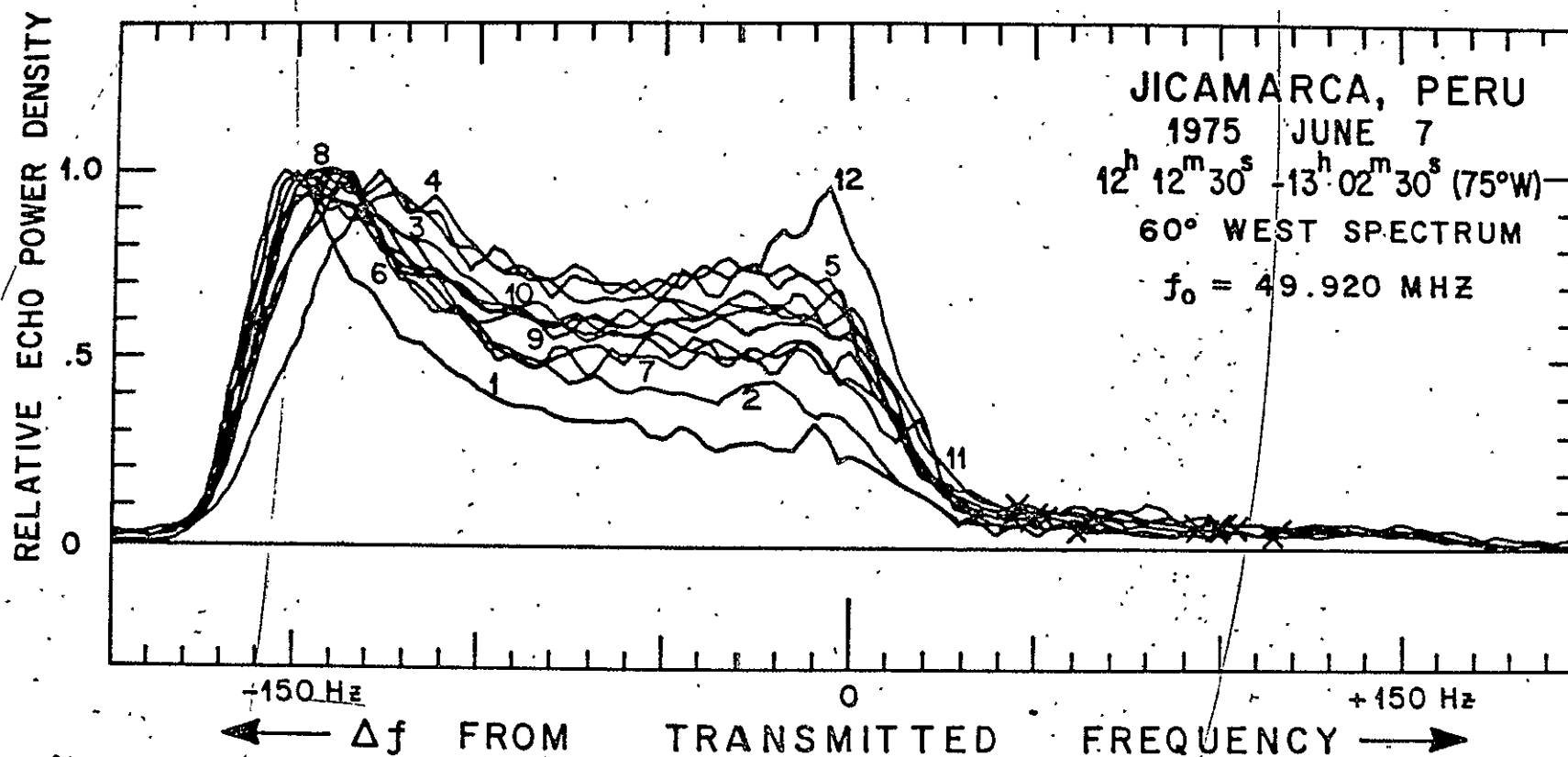
Nº2,751
ALOHT.-75

Fig. 64



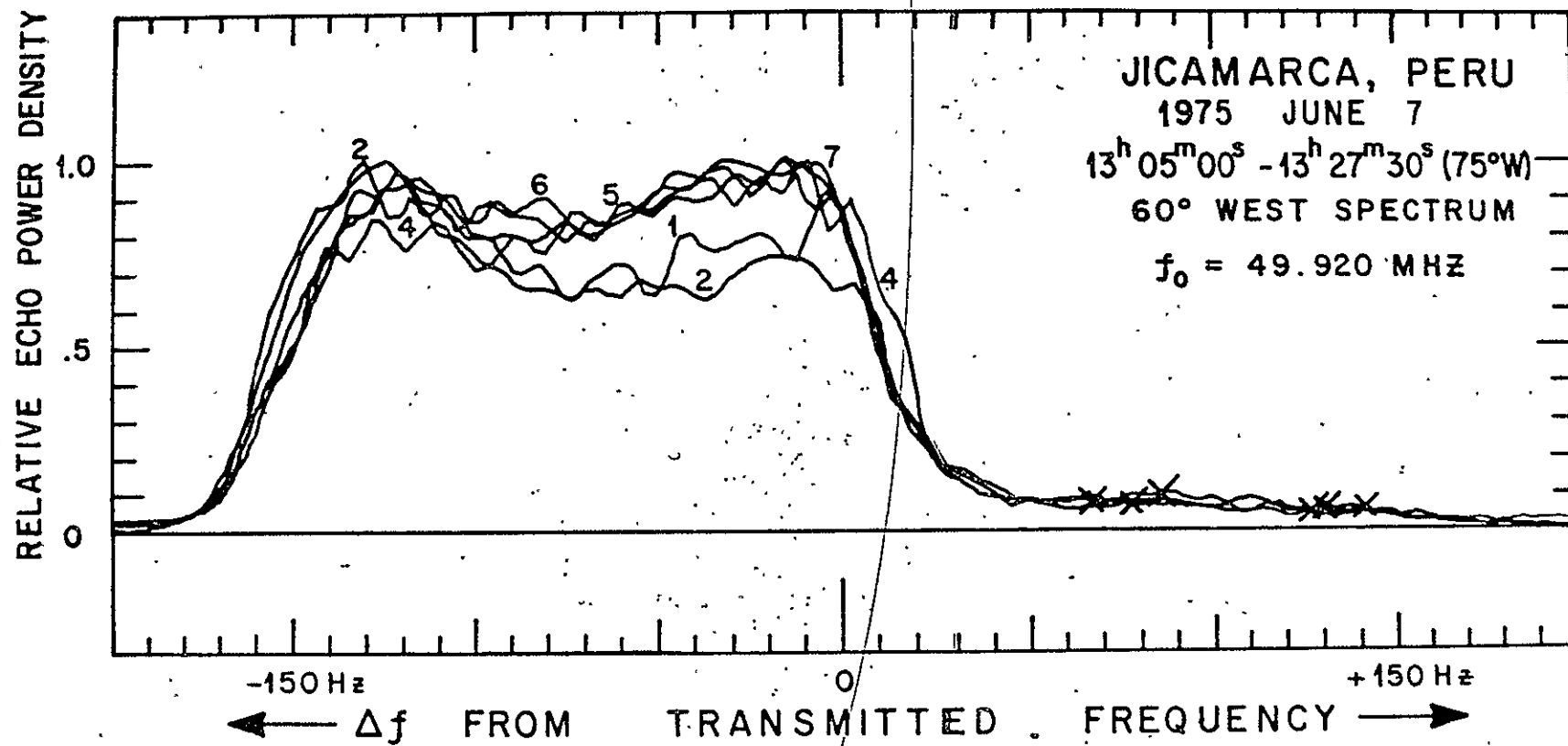
Nº2,752
ALOHY-75

Fig. 65



Nº 2,753
ALOH-75

Fig. 66



Nº 2,754
ALOMT-75

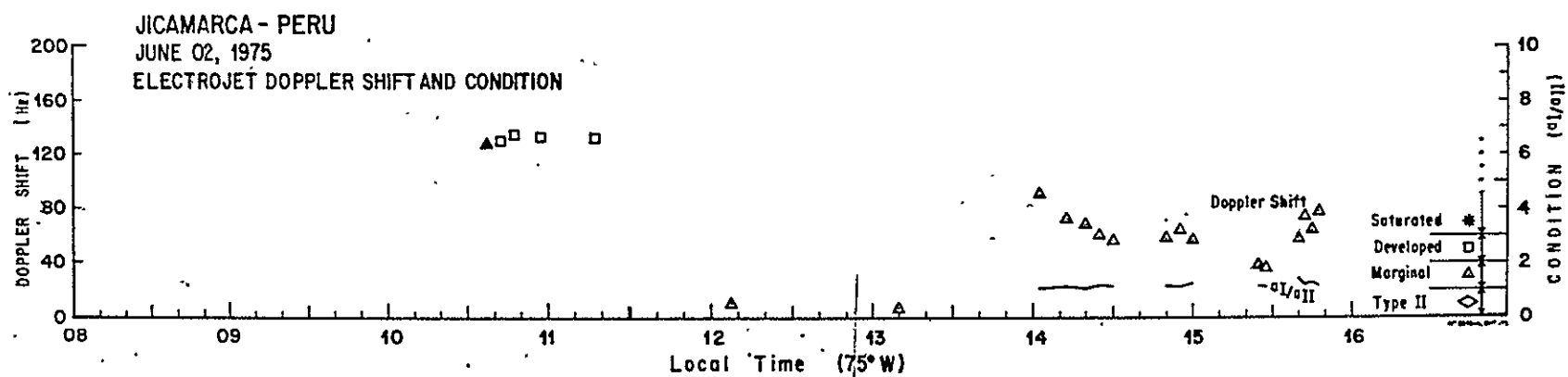
Fig. 67

APPENDIX D .

ELECTROJET DOPPLER SHIFT AND CONDITION

FIGURE CAPTIONS

Fig. 68 to 72 Electron temperature and condition as function of local time (75°W) for the dates indicated in the figures.



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Fig. 68

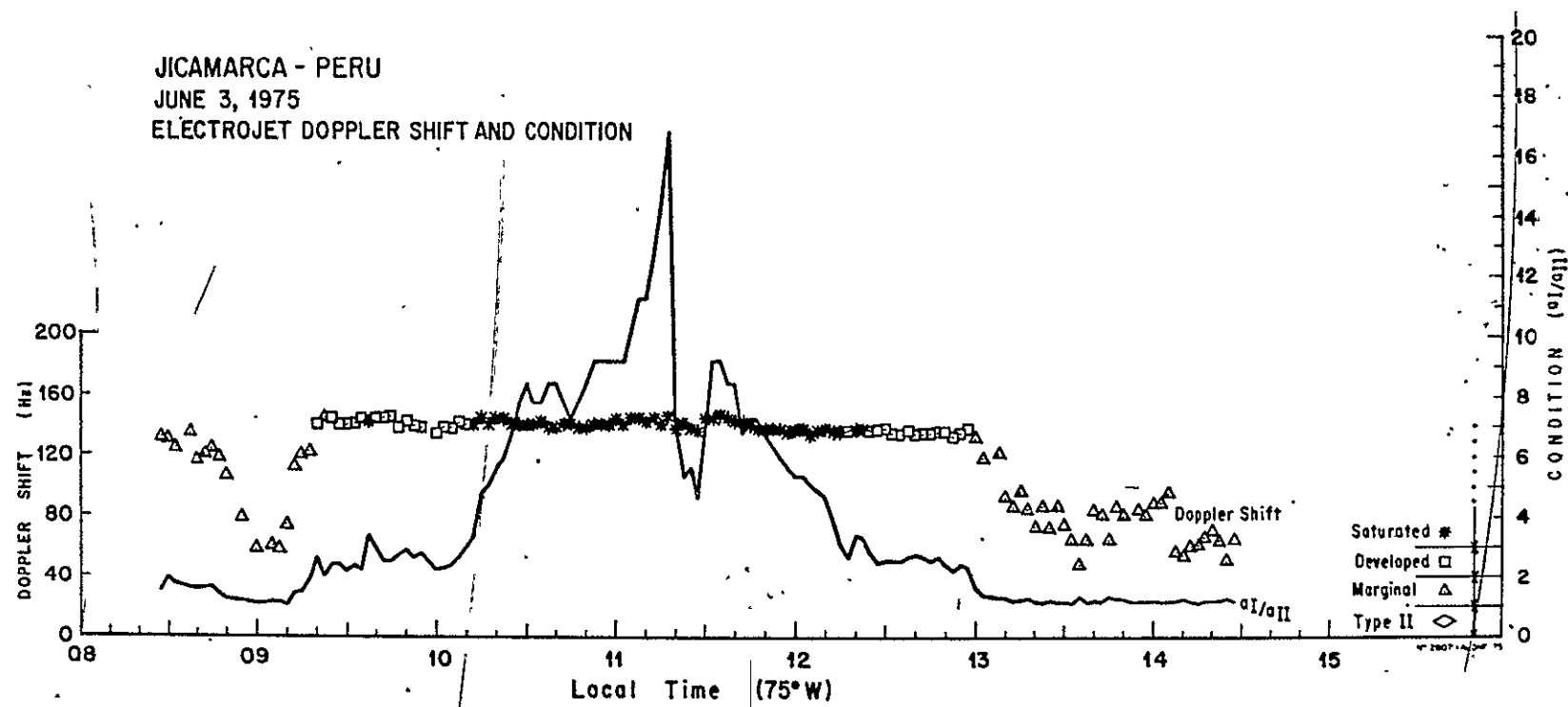
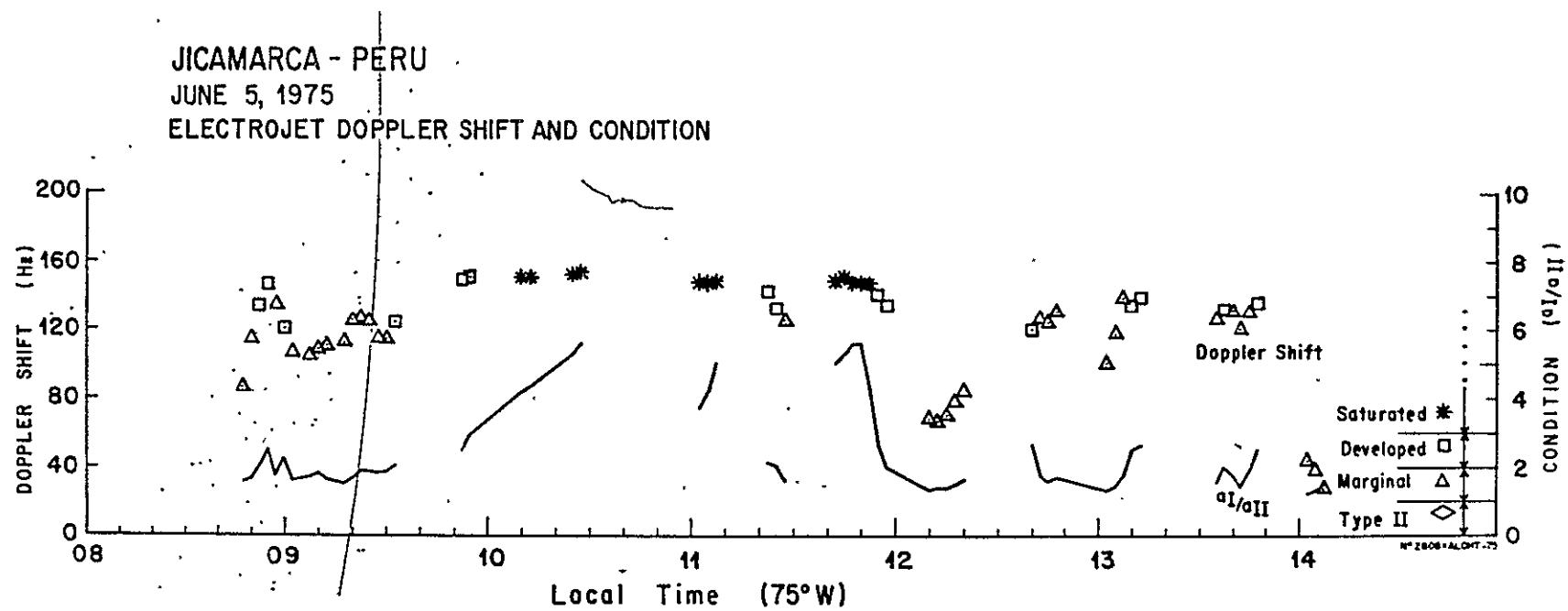


Fig. 69

C-2



JICAMARCA - PERU

JUNE 6, 1975

ELECTROJET DOPPLER SHIFT AND CONDITION

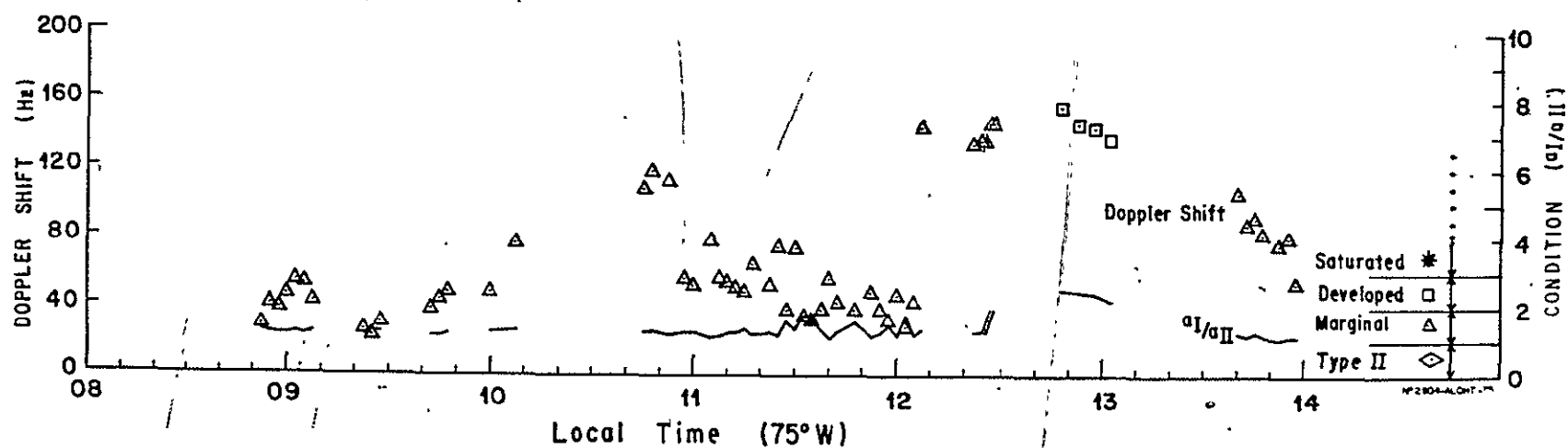


Fig. 71

JICAMARCA - PERU
JUNE 7, 1975
ELECTROJET DOPPLER SHIFT AND CONDITION

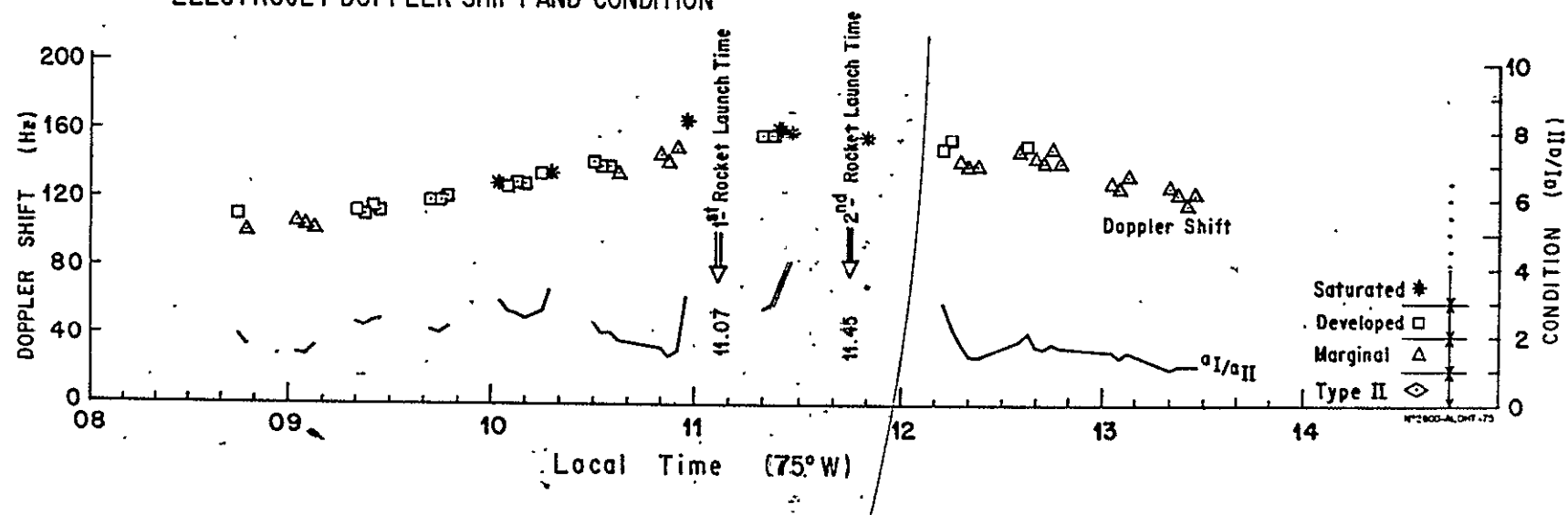


Fig.72

APPENDIX E

150 KM ECHOING REGION

FIGURE CAPTIONS

Fig. 73 to 82 Photographic records of the 150 km Echoing Region on June 7 1975 at the local times (75°W) indicated in each photograph. The first pulse corresponds to 155 km and the interpulse distance is .25 km.

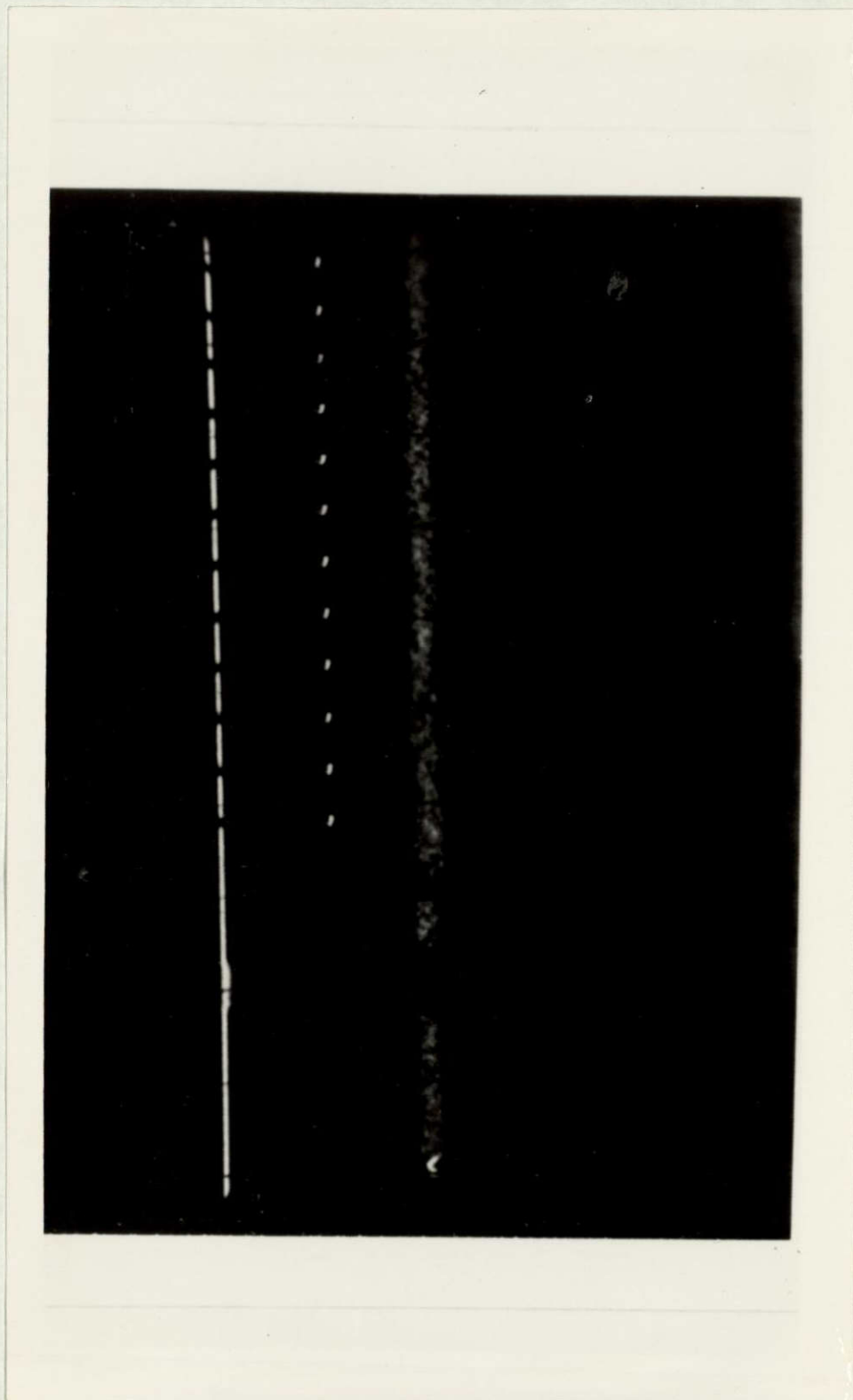


Fig. 73

PRECEDING PAGES BLANK NOT FILMED

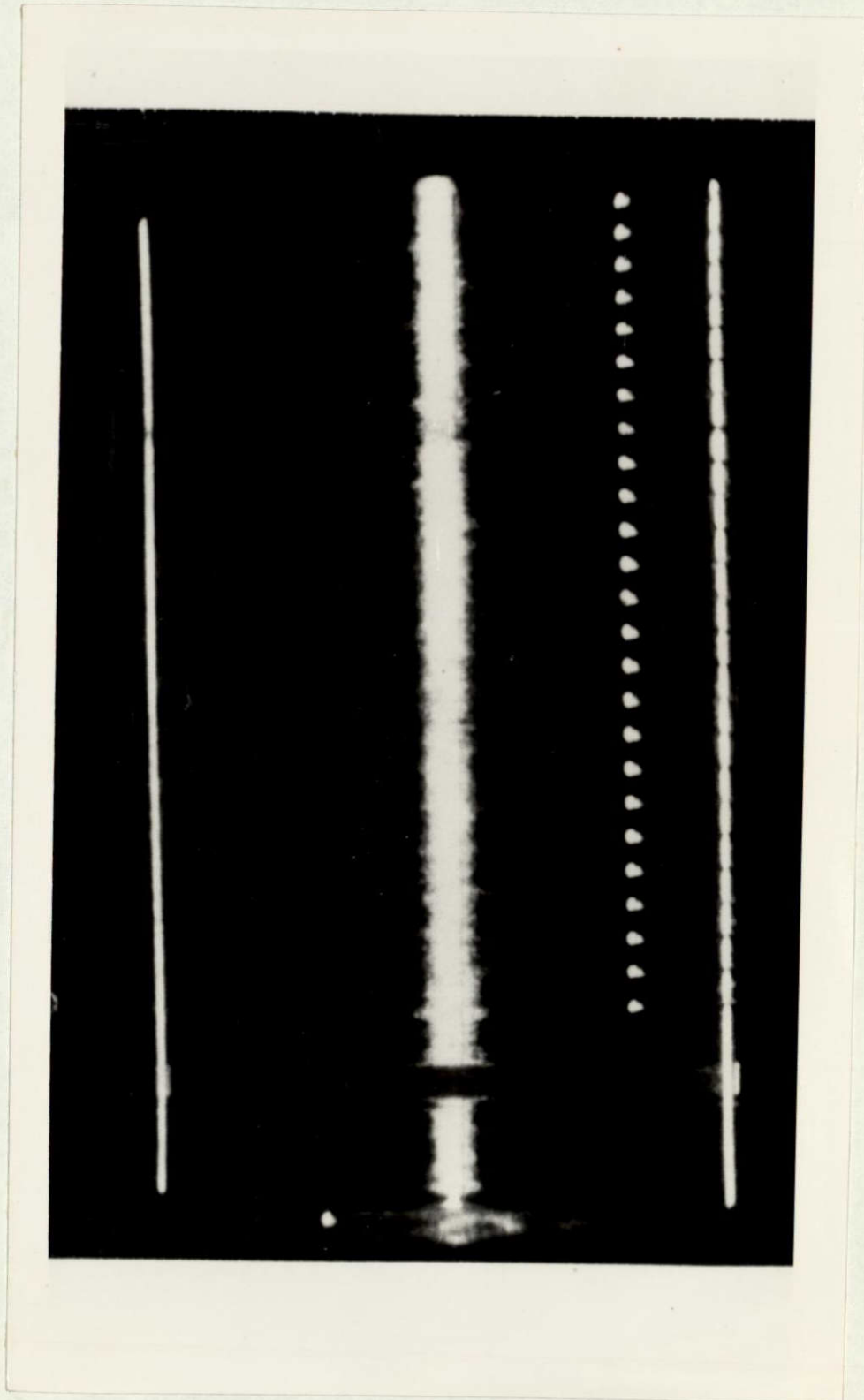


Fig. 74

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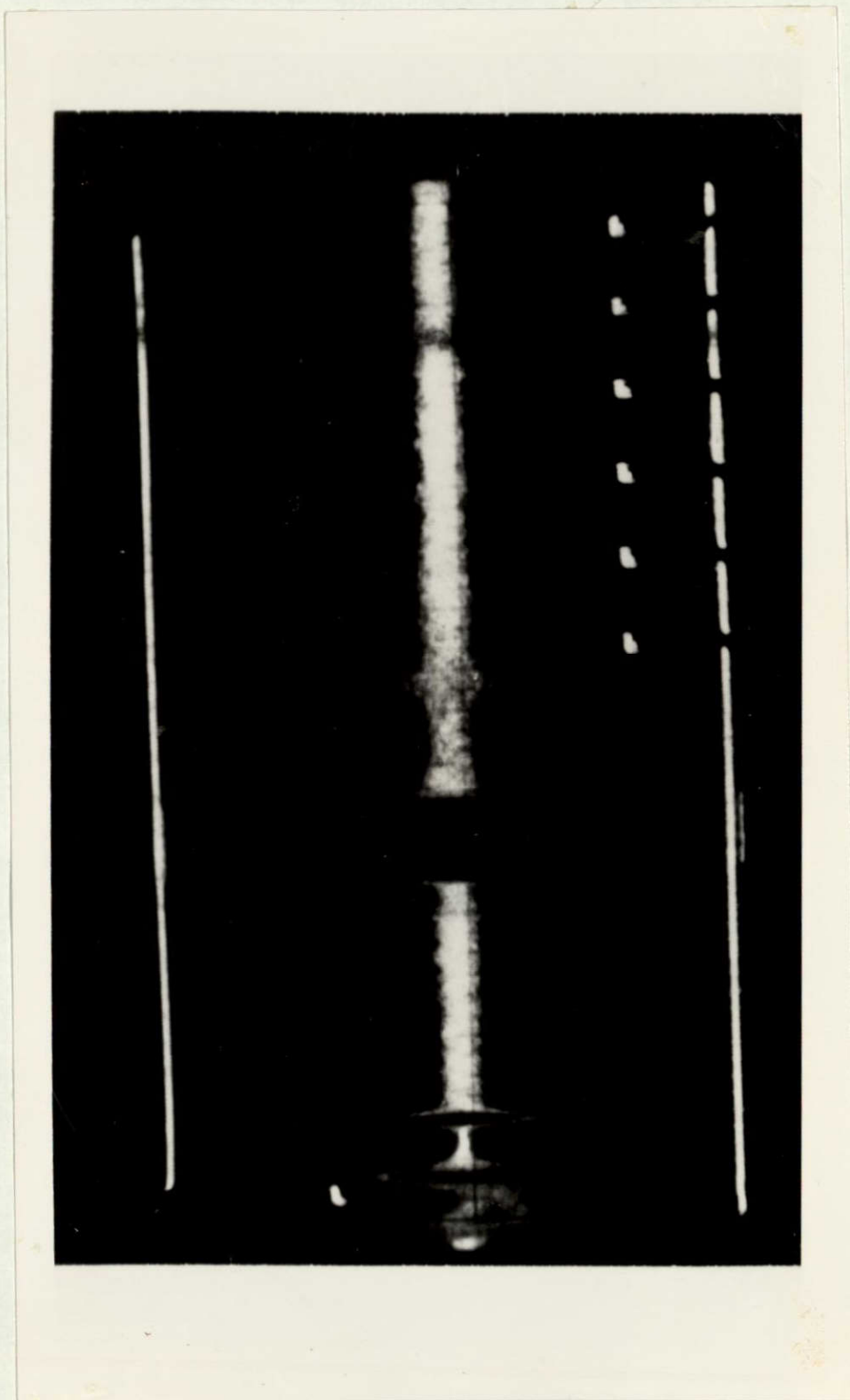


Fig. 75

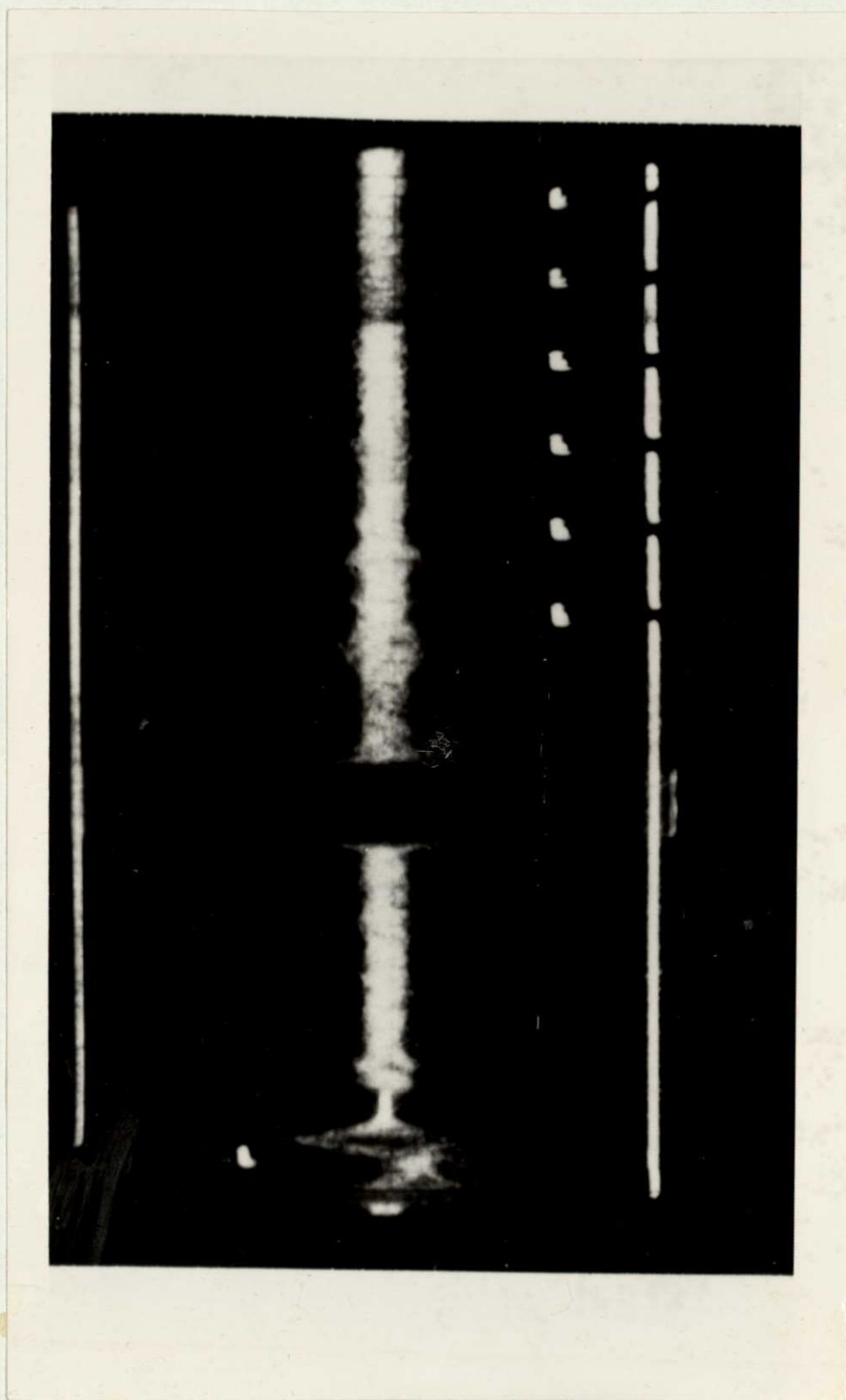


Fig. 76

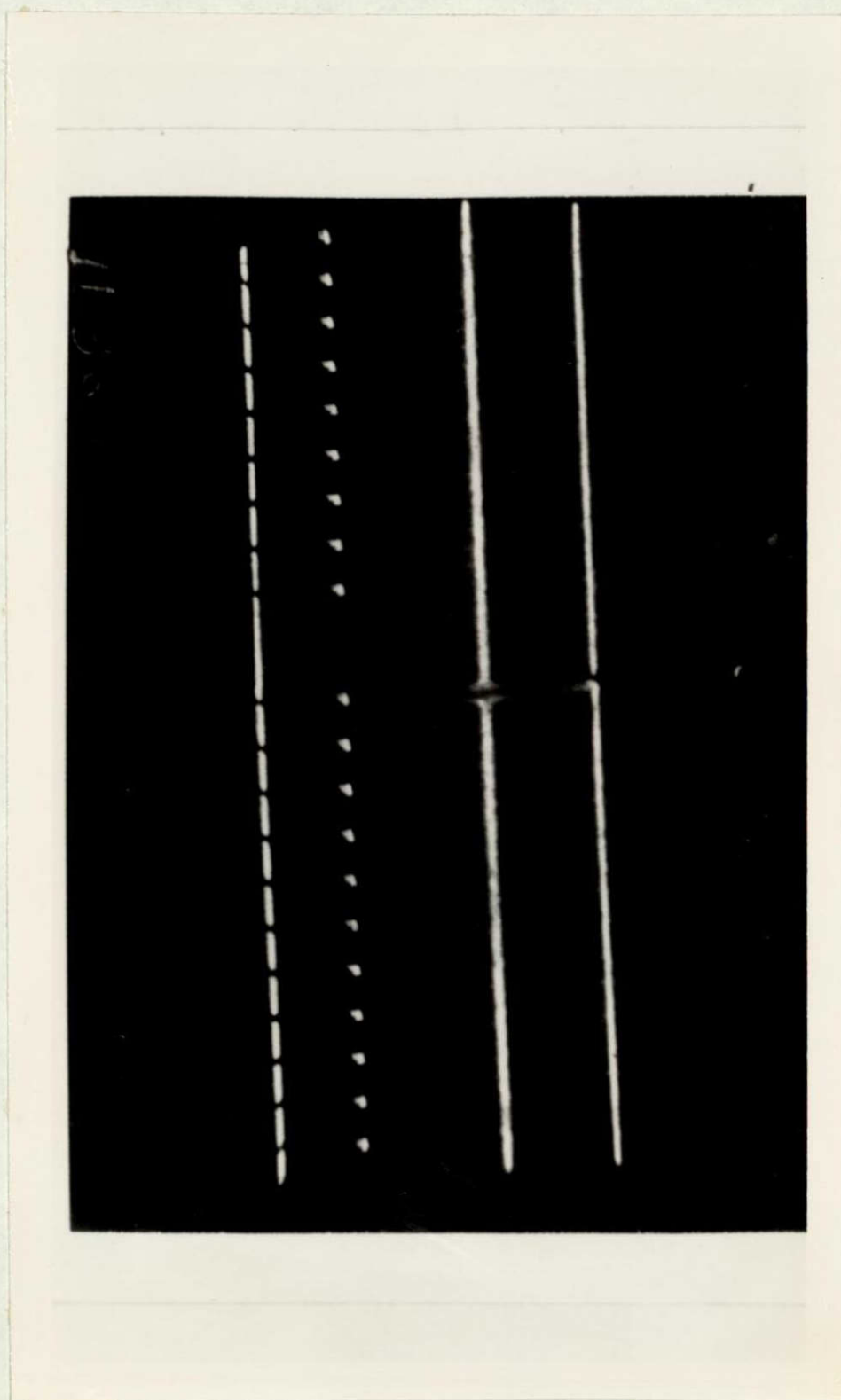


Fig. 77

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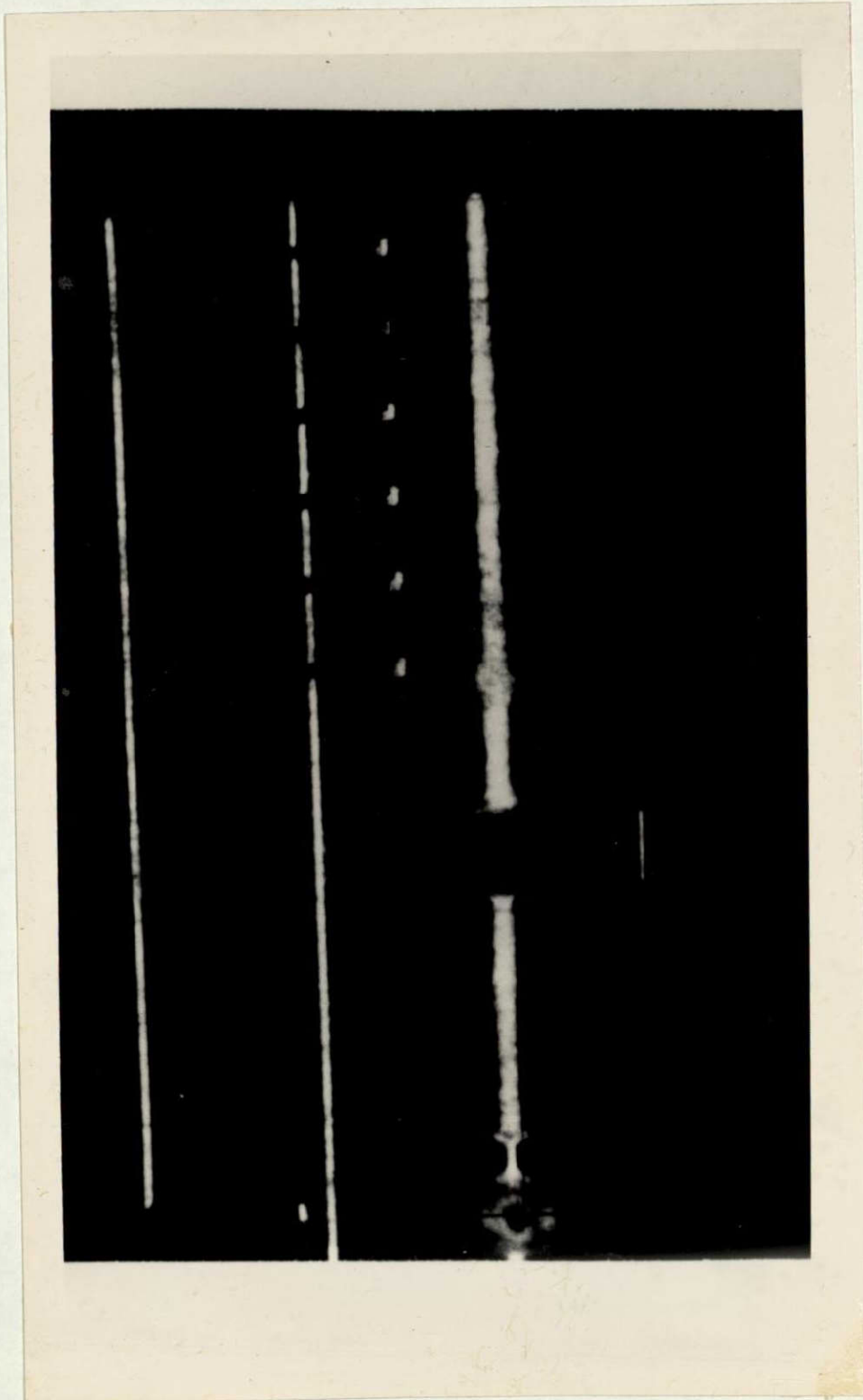


Fig. 78

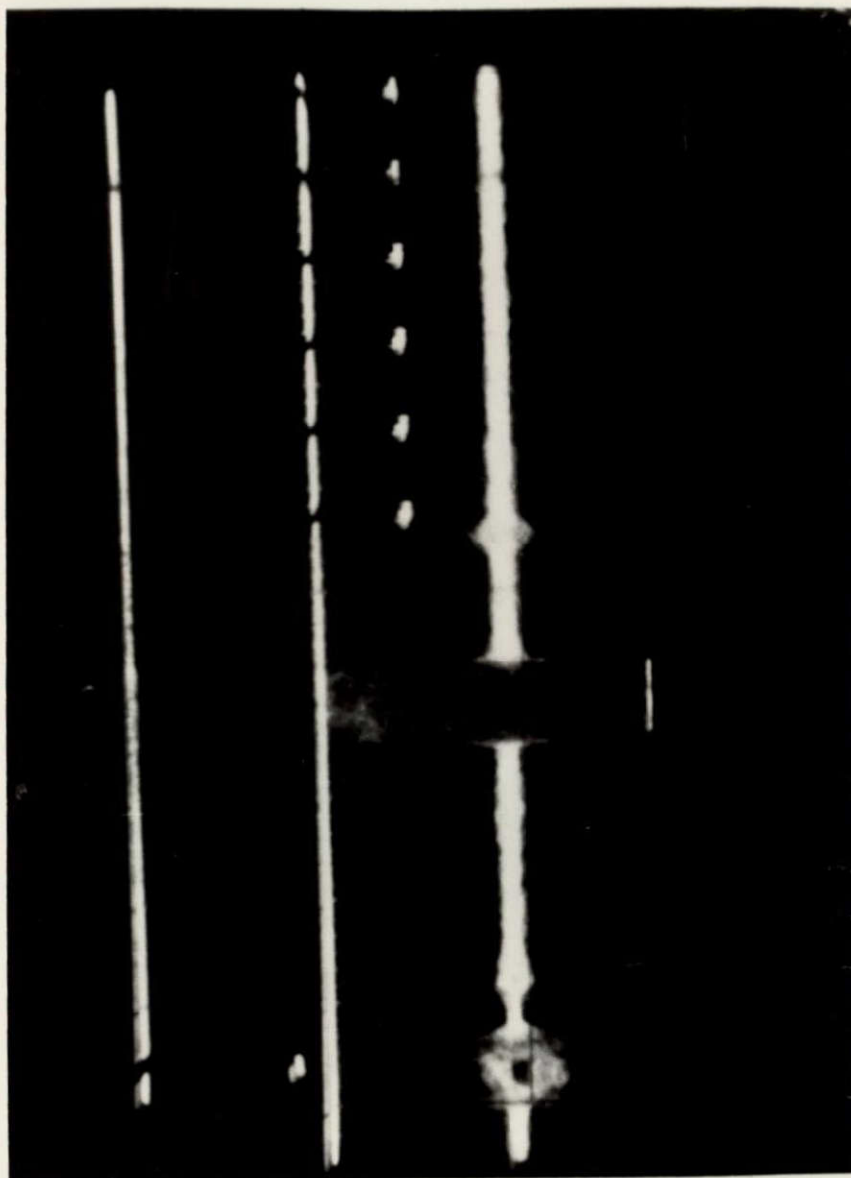


Fig. 79.

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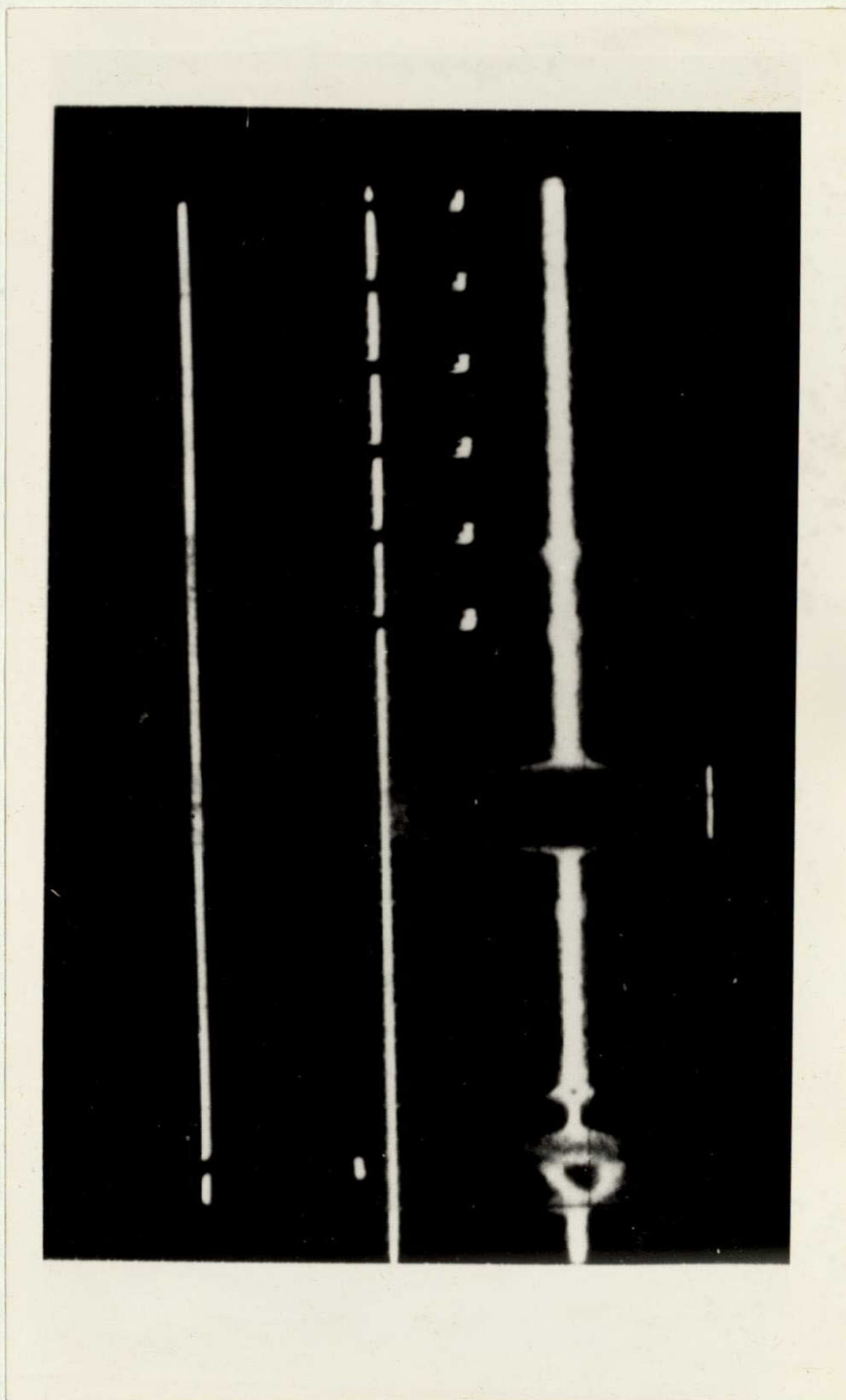


Fig. 80

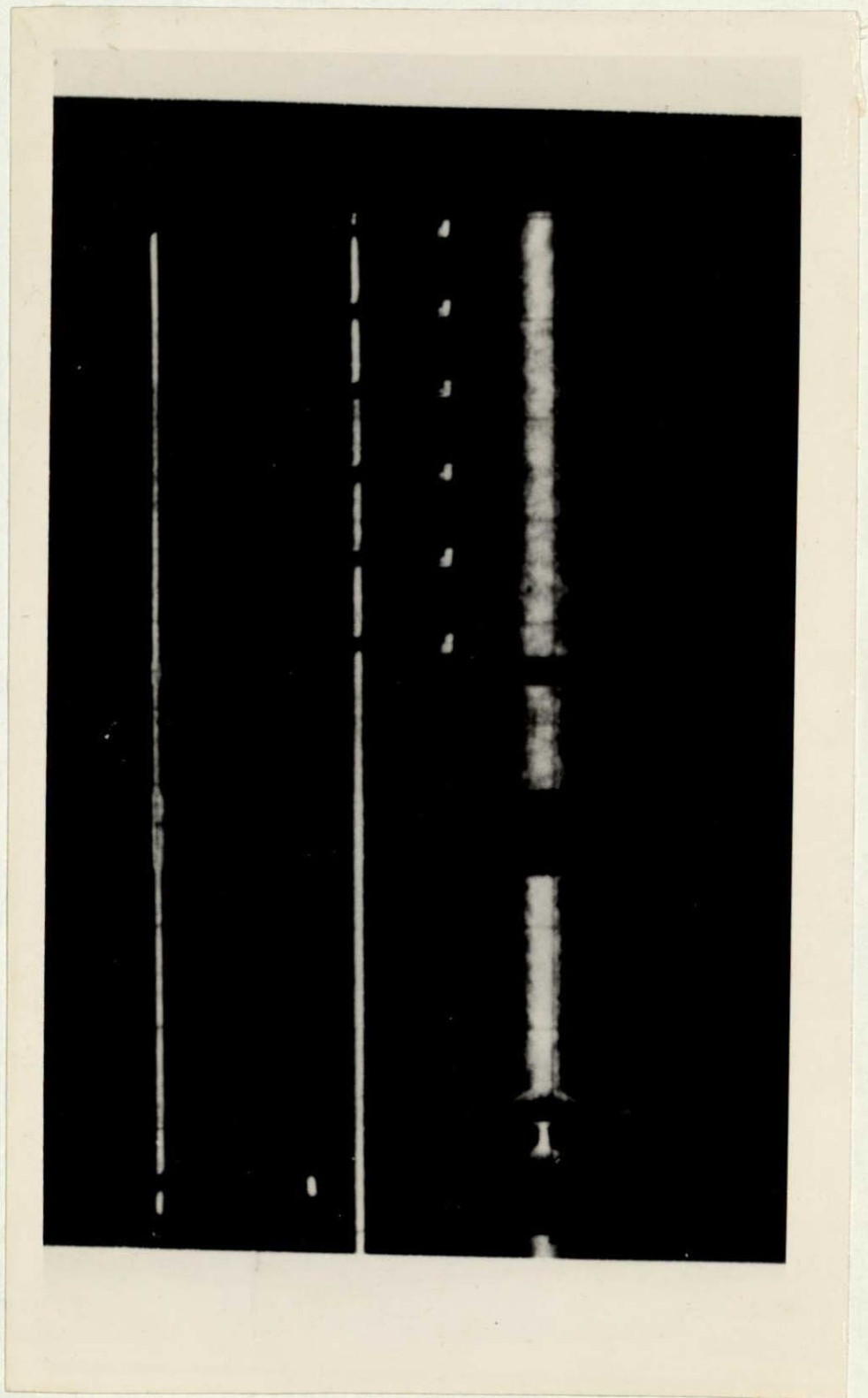


Fig. 81

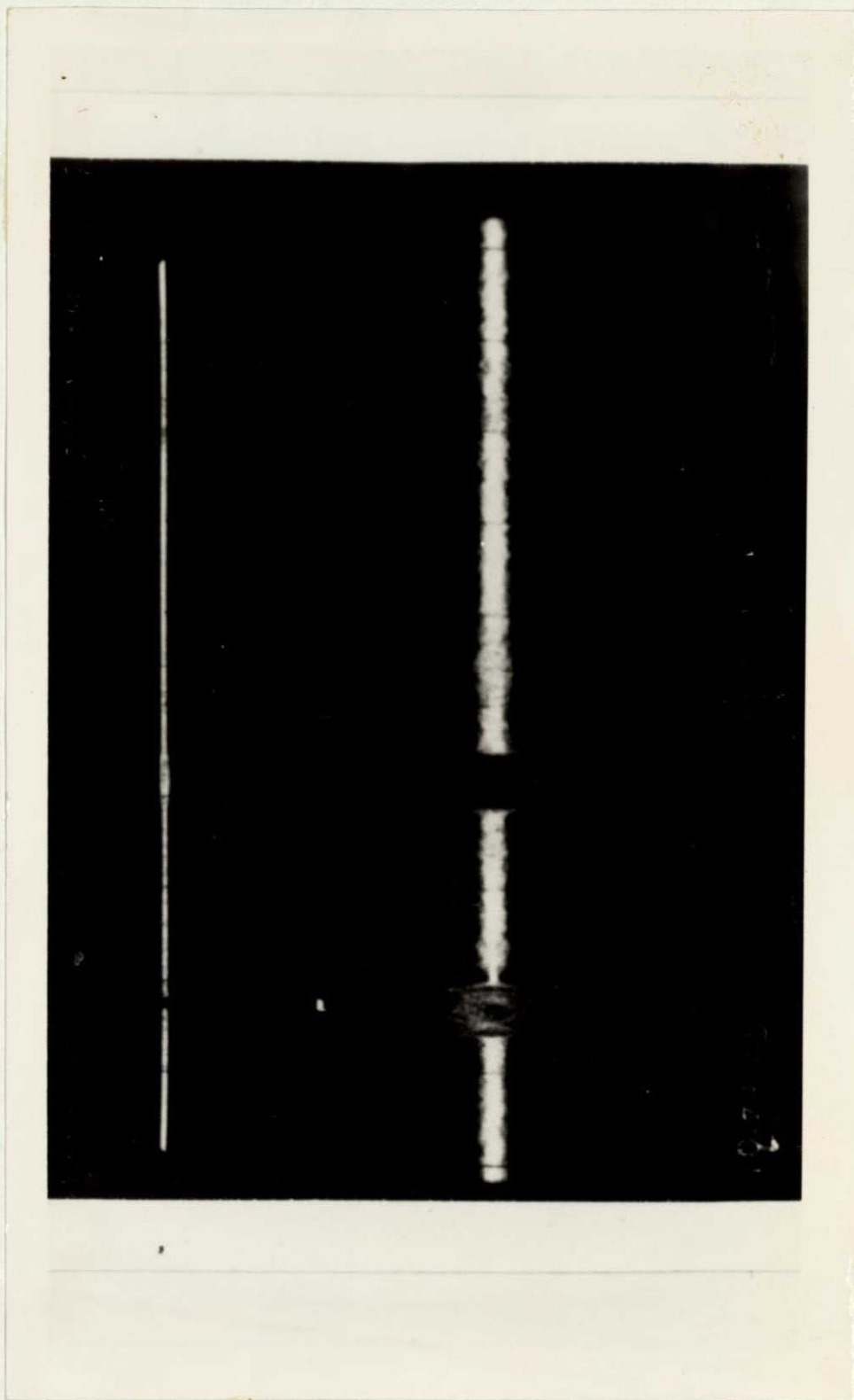


Fig. 82